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PRIMARY PROPULSION/LARGE SPACE SYSTEMS INTERACTION STUDY

by J. V. Coyner, R. H. Dergance,
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prepared for

NASA Lewis Research Center
Contract NAS3-21955

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16. Abstract

An interaction study was conducted between propulsion systems and large space structures to determine the effect of low-thrust primary propulsion system characteristics on the mass, area, and orbit transfer characteristics of Large Space Systems (LSS). The LSS which were considered would be deployed from the Space Shuttle orbiter bay in low-earth-orbit, then transferred to geosynchronous equatorial orbit by their own propulsion systems. The types of structures studied were the expandable box truss, hoop and colum, and wrap radial rib-each with various surface mesh densities. The impact of the acceleration forces on system sizing was determined and the effects of single-point, multi-point, and transient thrust applications were examined.

Orbit transfer strategies were analyzed to determine the required velocity increment, burn time, trip time, and payload capability over a range of final acceleration levels. Variables considered were number of perigee burns, delivered specific impulse, and constant thrust and constant acceleration modes of propulsion. Propulsion stages were sized for four propellant combinations; oxygen/hydrogen, oxygen/methane, oxygen/kerosene, and nitrogen tetroxide/monomethylhydrazine, for pump-fed and pressure-fed engine systems. Two types of tankage configurations were evaluated-minimum length to maximize available payload volume and maximum performance to maximize available payload mass.

Integration of LSS, orbit transfer strategy, and propulsion analysis results indicated an oxygen/hydrogen propulsion stage with a pump-fed, multiple burn engine operating at a final (stage burnout) thrust level in the range of 3100 to 4200 N delivers the maximum deployed diameter for the LSS structural concepts which were considered.

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FOREWORD

This report was prepared by the Martin Marietta Corporation, Denver Aerospace, under Contract NAS3-21955. The contract was administered by the Lewis Research Center of the National Aeronautics and Space Administration, Cleveland, Ohio. The study was performed from September 1979 to December 1980 and the NASA-LeRC Project Manager was Mr. D. D. Scheer.

The authors wish to acknowledge the contributions of the following individuals to this program: Mr. A. C. Park and Mr. M. K. Umbreit for their LSS analyses; Dr. D. E. Cornick for the mission analyses; and Mr. M. E. Draznin, Mr. K. M. Hamlyn, and Mr. L. R. Redd for their propulsion system analyses.

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SUMMARY

The interactions of a family of propulsion systems, mission parameters, and Large Space Systems (LSS) have determined the allowable acceleration range, orbit transfer requirements, and stage concepts for movement of LSS from low earth orbit (LEO @ 296 km, 28.5° inclination) to geosynchronous earth orbit (GEO @ 35,889 km, 0° inclination) after deployment from the Space Shuttle.

Three generic classes of LSS - rib, truss, and hoop and column - have been statically and dynamically evaluated to determine the effects of steady state engine thrust and start/shutdown transient accelerations on LSS mass and area. These analyses also included the effects of nonstructural surface masses representative of a broad range of potential LSS payloads. Orbit transfer strategies have been analyzed to determine required velocity increment, burn time, trip time, and payload capability for a range of available accelerations. Variables considered were number of perigee burns, delivered specific impulse, and constant thrust and constant acceleration (throttling) engine concepts.

Propulsion stages were sized for 4 propellant combinations; oxygen/hydrogen, oxygen/methane, oxygen/kerosene, and nitrogen tetroxide/monomethylhydrazine, at 3 mixture ratio points for pump-fed and pressure-fed configurations. The range of propellant loads considered in these analyses was consistent with an acceleration range that was compatible with LSS characteristics and orbit transfer strategies. Two generic classes of tankage configurations were evaluated - minimum length to maximize available payload volume and maximum performance to maximize available payload mass.

Integration of LSS, orbit transfer strategy, and propulsion analysis results indicated an oxygen/hydrogen propulsion stage with a pump-fed, multiple burn engine operating at a final (stage burnout) thrust level in the range of 3100 to 4200 N delivers the maximum deployed diameter for the LSS structural concepts which were considered.

I. INTRODUCTION

The availability of the Space Shuttle Transportation System (STS) in the early 1980s will make it feasible to produce on-orbit Large Space Systems (LSS). Studies performed by various agencies of government (NASA, DOD), Martin Marietta, and the remainder of the aerospace industry forecast that large antennas and platforms will be required either in low earth orbit (LEO) or in geosynchronous orbit (GEO).

In general terms, large space structures are classified as either deployable or erectable, depending upon the process used to place them into operational status. With deployable structures, manufacturing and assembly takes place on the ground, and then the completed assembly is flown into space in a high density folded form where it is deployed. The concept of erectable structures refers to assembly in space either by a building crew or by remote manipulation. Propulsion systems required to transfer these general types of structures from LEO to GEO can be either high or low thrust, depending upon the load bearing capability of the structure which depends upon the method and location selected for the final assembly.

The objective of this study program was to determine the effects of low-thrust primary propulsion system characteristics on the mass, area, and orbit transfer characteristics of Large Space Systems, including basic structural elements as well as nonstructural masses (antenna surface, payload subsystem for a phased array, solar array, etc.) The specific objectives of this program are delineated below:

1) Determine the design characteristics of various classes of Large Space Systems which are impacted by the primary propulsion thrust required to effect orbit transfer;

2) Determine the influence of primary propulsion steady state and transient thrust on the mass and area of designated LSS concepts;

3) Determine the effect of selected primary propulsion system characteristics on deliverable payload mass from low earth orbit to high earth orbit;

4) Determine the characteristics of selected pressure-fed and pump-fed stages for orbit transfer of LSS and the effect of these stages and Space Shuttle constraints on mass and volume available for packaged Large Space Systems; and

5) Determine relative merits of selected primary propulsion systems in terms of deliverable LSS mass, area, and/or length available for payload in the Orbiter cargo bay.

The technical effort is divided into five separate tasks which are summarized in the following paragraphs.

Task I - CHARACTERIZATION OF LARGE SPACE SYSTEMS

The objective of this task was to establish and compile those design characteristics of various classes of Large Space Systems (LSS) which affect

the mass/area relationship of the system and which were affected by the primary propulsion thrust necessary in the orbit transfer of the system. The generic classes of LSS to be considered in this study included platforms, booms, paraboloids, and hybrids of these three categories. Since there were a variety of structural concepts, both deployable and erectable, within each class and a variety of potential mission requirements were satisfied by these various configurations, this task considered mission-peculiar parameters, such as antenna surface mass and other components, that affect structural response in determining the LSS concepts recommended for further evaluation.

Task II - THRUST AND THRUST TRANSIENT EFFECTS

The objective of this task was to conduct parametric analyses of the recommended concepts from Task I to determine the influence of primary propulsion thrust on LSS mass and area.

The results of this task provided the following data:

1) LSS concept mass as a function of area and thrust-to-mass ratio (T/M) assuming constant thrust and a single point of thrust application;

2) The effects of startup and shutdown thrust transient on the results determined in (1) above. Thrust was assumed to vary linearly with time, and the time interval ranged from instantaneous application or unloading of thrust to a time at which transients do not influence the LSS mass and area;

3) LSS concept mass as a function of area and thrust-to-mass ratio assuming constant thrust and multiple points of thrust application.

Task III - PROPULSION SYSTEM PERFORMANCE

The objective of this task was to parametrically determine the deliverable mass and engine burn times as functions of thrust-to-mass ratio and number of engine burns when transferring the LSS from low earth orbit (LEO) at 296 Km circular at 28.5° inclination to geosynchronous earth orbit (GEO) at 35,889 Km circular at 0° inclination.

Analyses in this task assumed a start burn mass of 27,200 Kg for the expendable stage plus payload and was conducted over the study range of T/M generated in Task II.

Task IV - PROPULSION SYSTEM MASS AND VOLUME

The objective of this task was to determine the characteristics, including mass fraction, length, diameter, and center of gravity, of selected pressure-fed and pump-fed propulsion stages for low-thrust orbit transfer of Large Space Systems and to determine the influence of these stage characteristics and Space Shuttle constraints on the mass and volume available for packaged large space systems.

The range of loaded stage mass for which the parametrics were generated were based on the results of the previous tasks, and, in particular, Task III. The recommended T/M ratio range was based on the results of Task II.

Stage configurations were developed for the following propellant combinations and associated mixture ratios (MR):

1. oxygen/hydrogen (LO_2/LH_2) - MR from 5 to 7;

2. oxygen/methane (LO_2/LCH_4) - MR from 3.4 to 4.0:

3. oxygen/kerosene (LO_2/RP-1) - MR from 2.8 to 3.2; and

4. nitrogen tetroxide/monomethylhydrazine (N_2O_4/MMH) - MR from 1.8 to 2.6.

For each propellant combination shown above, conventional and minimum length tankage configurations were evaluated for pressure-fed and pump-fed engines.

Task V - PROPULSION SYSTEM COMPARISONS

The objective of this task was to determine the relative merit of the various primary propulsion system characteristics studied in Task II, III, and IV for each of the LSS concepts.

The primary factors used in establishing the relative merit of the various primary propulsion characteristics were deliverable LSS mass and area and/or length available for payload in the Orbiter cargo bay.

II. CHARACTERIZATION OF LARGE SPACE SYSTEMS

Characteristics of Large Space Systems (LSS) that are influenced by primary propulsion thrust had to be determined in sufficient detail that representative concepts and variations in design characteristics could be recommended for study in the remainder of the program.

An extensive literature search of 110 documents and subsequent evaluation and characterization of LSS concepts and missions resulted in three generic configurations being selected as most representative of a broad spectrum of requirements. Key variables considered in the evaluation process were:

- Mission parameters as manifested by:
  - LSS Diameter
  - Operational Altitude
  - Surface Mass Density (Kg/m^2)
  - Thrust-to-Mass Range
- Structural Configuration:
  - Structural Mass Density, Mass/Deployed Surface Area (Kg/m^2)
  - Stowage Density (Kg/m^3)
  - Deployed Stiffness and Load Paths
  - Point of Thrust Application

A. Mission Parameters

Table II-1 presents the various applications as they relate to diameter, operational altitude, and configuration (dish, boom, or planar system). Typical missions are:

PSCS	- Personal Communication Spacecraft
ODSRS	- Orbiting Deep Space Relay Station
RADIOMETRY	- Earth Resources
SETI	- Search for Extraterrestrial Intelligence
RA	- Radio Astronomy
VLBI	- Very Long Baseline Interferometer
SBR	- Space Based Radar
SPS	- Space Power Satellite Power Generation

From these typical missions for planar and dish systems, a generic set of surface mass densities was derived which encompass the broad spectrum of requirements.

The low RF frequency ($<$ 20 GHZ) antenna surface (mass density = 0.05 Kg/m^2) is of a gold plated, 1.2 mil molybdenum wire, tricot knit mesh with a secondary drawing surface. The high RF frequency ($>$ 20 GHZ) antenna surface mass density of 3.42 Kg/m^2 is typical for a 1.3 cm thick honeycomb sandwich panel with graphite epoxy face sheet and metallized reflective surface. The radar antenna surface mass density of 0.15 Kg/m^2 is typical for a three layer phased array lens which includes the collecting surface, ground plane surface, radiating surface and distributed phase shifting RF modules. The power generating surface (mass density = 0.40 Kg/m^2) represents deployable lightweight solar array technology.

One potential mission that is not a continuous surface on a structure is the space-based geosynchronous platform. This system is typically a

TABLE II-1- LSS MISSION PARAMETERS, OPERATIONAL ALTITUDE AND DIAMETER (REF II-1)

	Applications		Potential Requirements
Dishes	Communications	Earth	30-m LEO; 100-m GEO
		Deep Space	30-m GEO; 200-m GEO
	Earth Observations	Resources	100-m GEO; 300-m GEO
		Recon-Optical	15-m GEO
	Exploration	SETI	30-m LEO; 300-m GEO; 3000-m GEO
		Astronomy	20-m GEO; 100-m GEO
	Power Transmission-Optical		30-m GEO
	Power Generation		1-Mile GEO
Booms	Position Finding		2-Mile GEO
	Communication, Low Freq		1-km LEO
Planar Surfaces	Propulsion Solar Sail		800-m
	Power Transmission		1-km GEO
	Communication/Facscimile Transmission		30-m GEO; 100-m GEO; 300-m GEO
	Power Generation		30-m GEO/LEO
	Power Generation		10-km GEO
	Illumination		1-km GEO
	Space Radar		200-m GEO

Time axis: 1980, 1985, 1990, 1995

truss-type platform with lumped mass payloads at the hard points on a truss. However, this configuration can be represented by the power generation and high frequency surface mass density parameters. For example, by lumping the 0.40 Kg/m^2 surface at the hard points of a box truss with 8.84m member sizes, an equivalent lumped mass platform payload of 31 Kg per node is obtained. By lumping 3.42 Kg/m^2 surface at the hard points of the truss, an equivalent lumped mass platform payload of 267 Kg per node is obtained. Therefore, science or communication platforms with payload lumped masses from 31 Kg to 267 Kg are represented by the selected surface mass densities.

B. Structural Parameters

Fourteen structural configurations were identified from the literature search (see Table II-2). The objective was to select from these concepts three configurations that represent the wide variety of structural and dynamic configurations. The majority of the fourteen concepts can be summarized into three generic classes of structure -- radial rib, hoop and column, and truss. Consequently, a representative structural concept within each generic class was selected.

The wrap radial rib was selected for rib-type structures. This concept has the most efficient stowage density of all the radial rib configurations, is the most mature in design development, is capable of diameters to 200 meters, and is relatively light compared to other radial rib systems.

The wrap-rib antenna consists of a hollow, doughnut-shaped hub to which a series of radial ribs, formed to the shape of a parabola, are attached. A lightweight reflective mesh is stretched between these ribs to form the paraboloidal reflecting surface. The feed system is usually located at the prime focus of the paraboloid by one or more deployable support booms. A sketch of the deployed wrap-rib antenna is shown in Figure II-1. To furl the reflector, the ribs are wrapped around the hollow hub with the mesh folded between them (Figure II-2).

The parabolic surface is formed by a flexible, lightweight reflective mesh supported along each of the radial ribs. The number of ribs or mesh panels used is dependent upon the desired root mean square (rms) surface accuracy, which, in turn, determines the gain of the antenna excluding the losses due to blockage by the feed support structure.

The hollow, doughnut-shaped support hub has mounting pads to interface the antenna system with a spacecraft or the Shuttle. It provides the support points for each radial rib and stowage area for the radial ribs and the reflective mesh. The hub supports the "in space" deployment and refurl mechanism as well as an "in space" surface-contour evaluation and adjustment system if such a system is used.

The flexible ribs are wrapped around a power-driven rotating spool that constrains the stored energy of the wrapped ribs and deploys the reflector surface at a controlled rate. The furling mechanism uses a sliding guide to "wipe" the ribs in a rotating manner back into their stowed configuration. The stowed configuration may be as small as one-fortieth of the deployed diameter of very large antennas. The stowed configuration also lends itself to high load-carrying capability.

TABLE II- 2 - STRUCTURAL CONFIGURATIONS

CONCEPT	ORGANIZATION	DIAMETER* RANGE, M
UMBRELLA RADIAL RIB DOUBLE MESH ANTENNA	HARRIS (REF II-2)	3-25
WRAP RADIAL RIB ANTENNA	LOCKHEED (REF II-3)	30-200
ERECTABLE RADIAL RIB ANTENNA	GENERAL (REF II-4) DYNAMICS	30-200
RADIAL COLUMN RIB ANTENNA	HARRIS (REF II-2)	20-100
ARTICULATED RADIAL RIB ANTENNA	HARRIS (REF II-2)	20-40
MAYPOLE ANTENNA	LOCKHEED (REF II-5)	30-300
HOOP & COLUMN	HARRIS (REF II-2)	30-300
HOOP & COLUMN RADAR	GRUMMAN (REF II-6)	30-200
EXPANDABLE TETRAHEDRAL TRUSS ANTENNA	GENERAL (REF II-3) DYNAMICS	10-175
EXPANDABLE BOX TRUSS ANTENNA	MARTIN (REF II-7) MARIETTA	10-250
SUNFLOWER SOLID PANEL ANTENNA	TRW (REF II-8)	5- 20
EXPANDABLE ASTROCELL MODULE	ASTRO RESEARCH/ LANGLEY	5-100
ELECTROSTATIC MEMBRANE	GRC (REF II-9)	5-200
EXPANDABLE BOX TRUSS PLATFORM	MARTIN (REF II-7) MARIETTA	5-100

Note: Diameter limitations refer to single orbiter packaging with an orbit transfer vehicle.

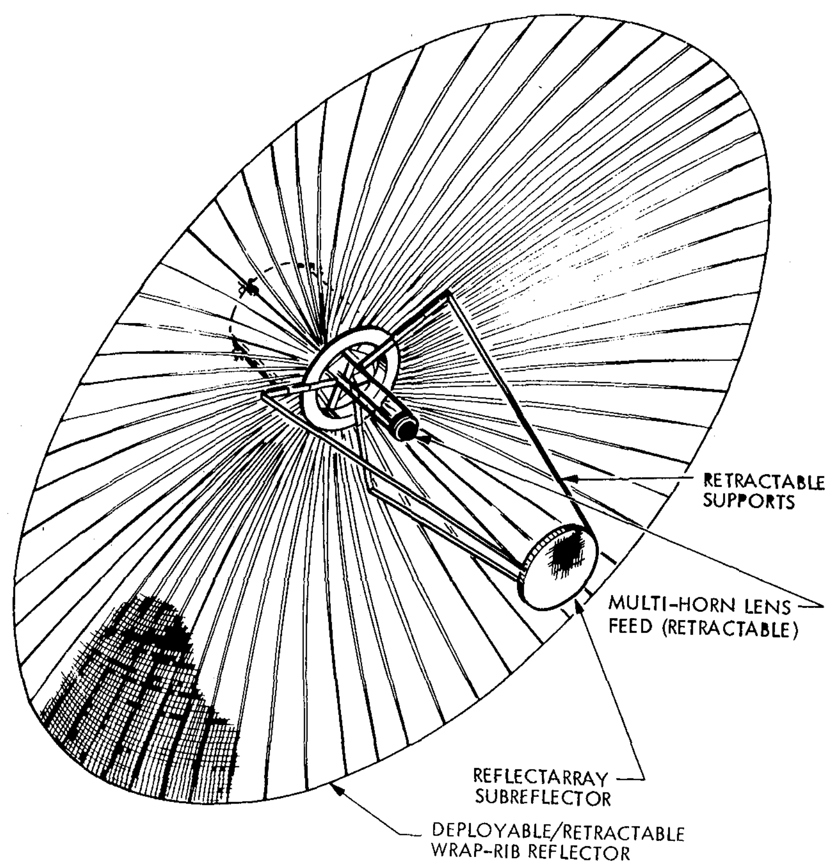


FIGURE II-1-TYPICAL LOCKHEED WRAP-RIB ANTENNA: DEPLOYED CONFIGURATION (REF II-5)

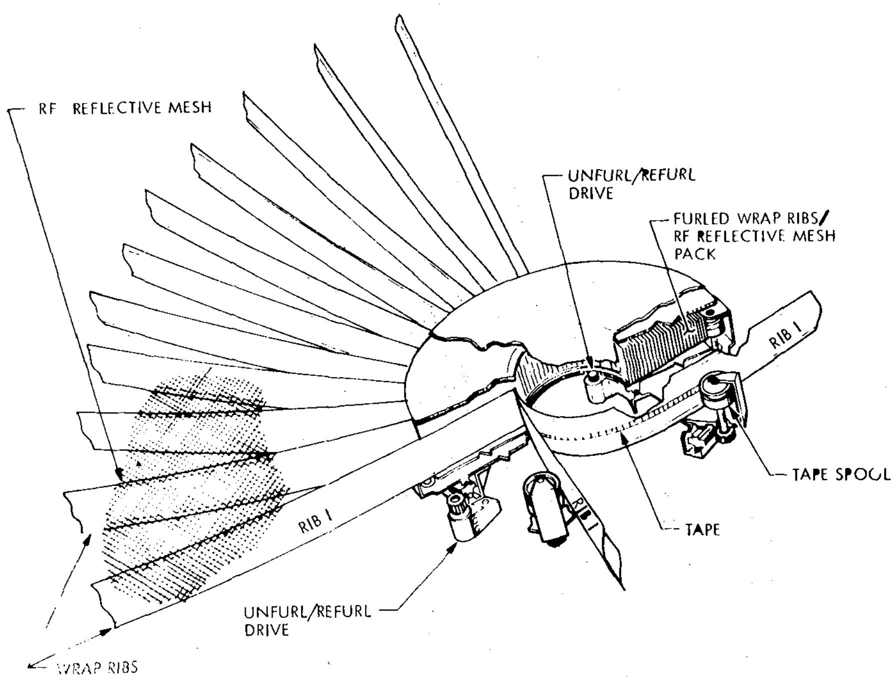


FIGURE II-2 LOCKHEED WRAP-RIB ANTENNA: FURLING MECHANISM (REF II-5)

The feed or feed array used with this concept is dependent upon the reflector size and intended use. It may be a single horn illuminating the total surface; a cluster of horns, each illuminating a portion of the reflector surface, but forming one coherent beam; or a cluster of feeds forming individual spot beams. The cluster of feeds also may be replaced by a phased array used as a feed for either single or multiple beams or to generate specially shaped or steerable beams.

Dependent upon reflector size, the deployable feed support structure could be a simple, powered, folding structural boom; a structurally formed boom that is elastically buckled for storage on powered spools; a modified scissors structural-type boom that is powered for extension and retraction; or some type of telescoping boom. The boom will use conventional thermal control or will be built from materials with low coefficients of thermal expansion to ensure precise positioning of the feeds under varying thermal environments.

The diameter range of the wrap radial rib is 30-200 meters where the actual maximum diameter is limited by the payload and stowage limits in the Orbiter. The primary mission application is a low frequency, large diameter reflector with a surface density of 0.05 Kg/m^2, however the radar surface mass of 0.15 Kg/m^2 was also analyzed. The point of thrust application is at the center of the hub along its longitudinal center line.

For the hoop and column concept, the Grumman planar phased array and the Harris reflector concept were selected. The Grumman approach is typical of planar structure for arrays or solar collectors, and the Harris approach is typical of curved reflector surfaces (Figures II-3 and II-4).

The Grumman space-fed phased-array concept is intended for design up to 200 meters in diameter for operation at L-band or S-band. Grumman developed this concept to the point of a preliminary design for a 60 m diameter antenna and a 1.3 m diameter mechanical model. The mechanical model was used to demonstrate and evaluate the basic mechanical conceptual design. Detailed design of a 200 m antenna was used in a NASTRAN finite element analysis, static and dynamic, to determine the tolerance-holding properties of the design. It was determined that tolerances can be held well under one one-hundreth of a wavelength at L-band.

The Grumman antenna concept is a planar-type array whose basic support structure is a "wire-wheel" type configuration. This concept development was centered around the design of 61 m diameter and 200 m diameter space-fed, phased-array antennas for operation at L-band.

The basic elements of the support structure include the drum, rim assembly, fore and aft stays, and telescoping mast. The phased array itself is composed of 32 to 72 gore panel assemblies and their tensioning devices. The compression rim assembly is located and supported about the drum by the spring-loaded radial stays that extend from the rim to reels located on the drum assembly. This basic configuration is the "wire-wheel". The antenna drum for the 61 m antenna is 7.1 m long and 1.47 m in diameter, and is fabricated principally of aluminum alloy in frame-reinforced, thin-skin cylindrical configuration. Two support rings, external to and supported by the drum, and a multiplicity of antenna gore edge/batten support studs transfer the deployable hardware launch loads to the primary structure. The compression rim assembly is composed of 32 thin-wall graphite/epoxy tubes, 5.96 m long and 10.2 cm in diameter. The radial stays are graphite/epoxy

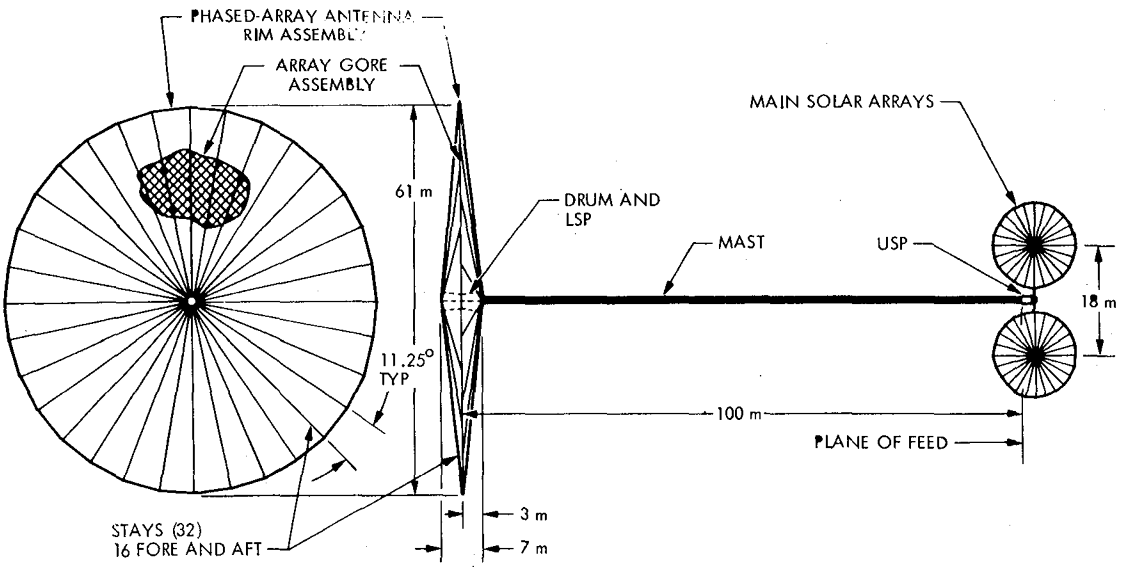


FIGURE II-3 BASIC STRUCTURAL ELEMENTS OF GRUMMAN PHASED-ARRAY CONCEPT (REF II-10)

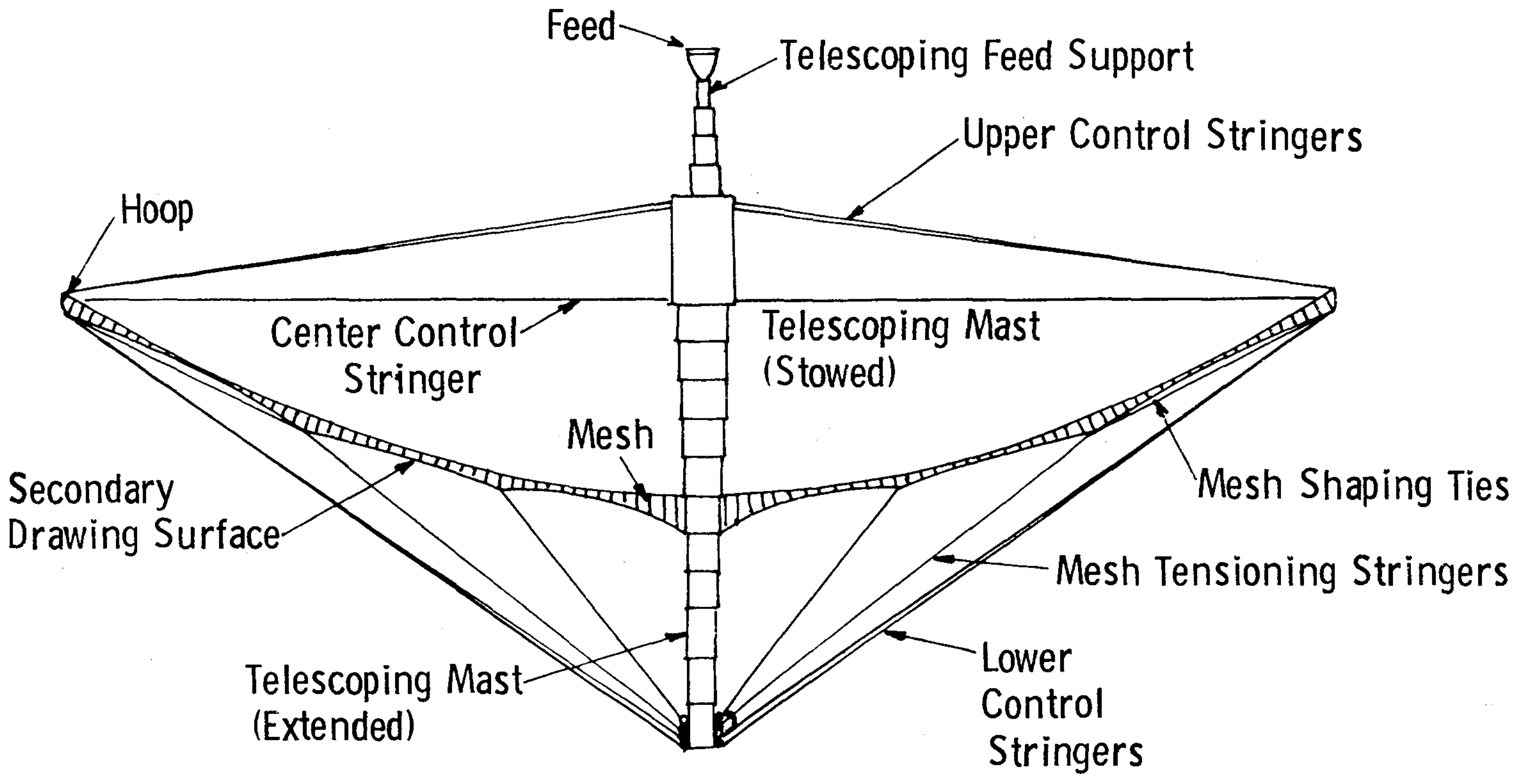


FIGURE II-4 HARRIS HOOP AND COLUMN CONCEPT
(REF II-10)

strips, 0.015 by 2.5 cm. The gore panel assemblies are tensioned between the rim and the drum so that they form a plane. Operation of the antenna at L-band requires a rim assembly radial tolerance of the radiating elements of less than 0.8 cm and axially less than 4.6 cm.

A 91.4 m Astromast locates and supports the antenna feed system and power source which consists of two deployable 14.2 m diameter solar arrays that are based on the same deployable antenna concept. The Astromast canister is located within the drum structure. This concept is also applicable for a large solar cell array power system.

The Harris Corporation hoop and column reflector antenna concept for self-erectable structures is intended for reflector designs up to 100 m in diameter (Figure II-4). This concept has been developed to the point of a preliminary design for sizes up to 45.7 m in diameter and a 1.8 m diameter conceptual demonstration model. This 1.8 m mechanical model was used to verify the basic conceptual design in addition to leading to solutions of the kinematic problems associated with deployment. The preliminary design has been complemented with the development of analytical techniques for prediction of antenna performance for larger size structures.

The fundamental elements of the support structure include the hoop; upper, lower, and center control stringers; and the telescoping mast. The reflector consists of the mesh, mesh shaping ties, secondary drawing surface, and the mesh tensioning stringers. The basic antenna configuration is a type of "may-pole", with a unique technique for contouring the RF reflective mesh.

The hoop's function is to provide a rigid, accurately located structure, to which the reflective surface attaches. It is comprised of 40 rigid sections which articulate at hinges joining adjacent segments. These segments consist of two tubular, graphite fiber members parallel to each other and attached to a long hinge member at each end. These long hinges allow the separation between the tubular members of the hoop segment required by the geometry of the mesh-secondary drawing surface. Torsion springs located in each hinge supply the total energy required to deploy the hoop.

The central column or mast is deployable and contains the microwave components and control mechanisms. It consists of tubular graphite/epoxy shell members that nest inside each other when stowed. Aside from housing various components, the mast provides attachment locations for the reflective surface and the stringers.

Five sets of stringers are used on the hoop and column concept. Three of these sets are used for hoop deployment and its control; the other two sets are used for mesh shaping. The hoop-control stringers are located at the upper end, the center, and the lower end of the extendible mast; they extend radially outward to their attachment positions at the hinges of the hoop. The upper and lower control stringers accurately position the hoop throughout its deployment. The center control stringers are used for rate control during deployment and for moving the hoop joints toward the mast and against their spring forces during the automated stowing sequence. The remaining two sets of stringers (mesh tensioning stringers) are located just above the lower control stringers and are used to shape the reflective surface into the proper contour. All of these stringers are made of stranded quartz cords for high stiffness and thermal stability.

The reflective surface is produced by properly shaping a knitted mesh fabric. The mesh is made of 0.03 mm diameter, gold-plated molybdenum wire. The mechanism that permits shaping of the mesh consists of numerous radial quartz stringers to which the mesh is directly attached (mesh surface stringers) along with a similar set of stringers (secondary drawing surface stringers) positioned beneath them. Short ties (mesh shaping ties) made of Invar wire connect the RF mesh surface stringers to the secondary drawing surface stringers. When the RF mesh tensioning stringers are tensioned, they in turn tension both the secondary drawing surface stringers and the mesh shaping ties to produce an essentially uniform pressure distribution of the mesh. This pressure distribution allows shaping of the mesh to a good approximation of a parabolic curvature. The surface accuracy is affected by the number and spacing of the mesh shaping ties. The greater the number of ties, the greater the surface accuracy.

Two groups of drive mechanisms are used in the hoop and column concept. One group, used to extend the mast, consists of one basic set of mechanisms for each section of the telescoping mast. The second group of drive mechanisms is used to adjust the control stringers and consists of motor-driven spools to which the stringers are attached. There are five sets of spools, one for each group of stringers. The spools are used to retract and discharge the stringers during the deployment and stowing sequence and are positioned around the mast in the locations described for the stringer attachments. A torque motor drives each set of spools independently, as required by the specific position and velocity of the hoop joint being controlled.

The diameter range of the hoop and column is 30-300 meters where the actual maximum diameter is limited by the payload and stowage volume in the Orbiter. The primary mission applications are a low frequency, large diameter reflector, a planar space based radar, and a planar solar array platform (surface mass density range of 0.05-0.15-0.40 Kg/m^2). The point of thrust application is at the lower end of the telescoping mass, perpendicular to the deployed hoop.

For the truss concept, the box truss structure was selected (Figure II-5). This concept has the most efficient stowage density of all the truss concepts, is capable of diameters in excess of 200 meters, and is relatively light compared to other truss concepts.

Figure II-6 illustrates the basic concept's operating principle. Vertical members connect the front and back surfaces of the truss and carry support posts upon which the surface is mounted. Surface tubes, hinged in the middle, connect each vertical member to each adjacent member. Each truss square, composed of surface tubes and vertical members, is stabilized by diagonal tension tapes. For stowage, each surface tube folds about its mid-link hinge and the diagonal tapes telescope.

Structural deployment is accomplished in low earth orbit (LEO) near the Orbiter in a sequence of controlled steps. Following verification that each step has been completed successfully, the next set of rows is deployed. Symmetrical pairs are always deployed simultaneously to balance reaction forces. This preserves the deploying structure's attitude and center of gravity position.

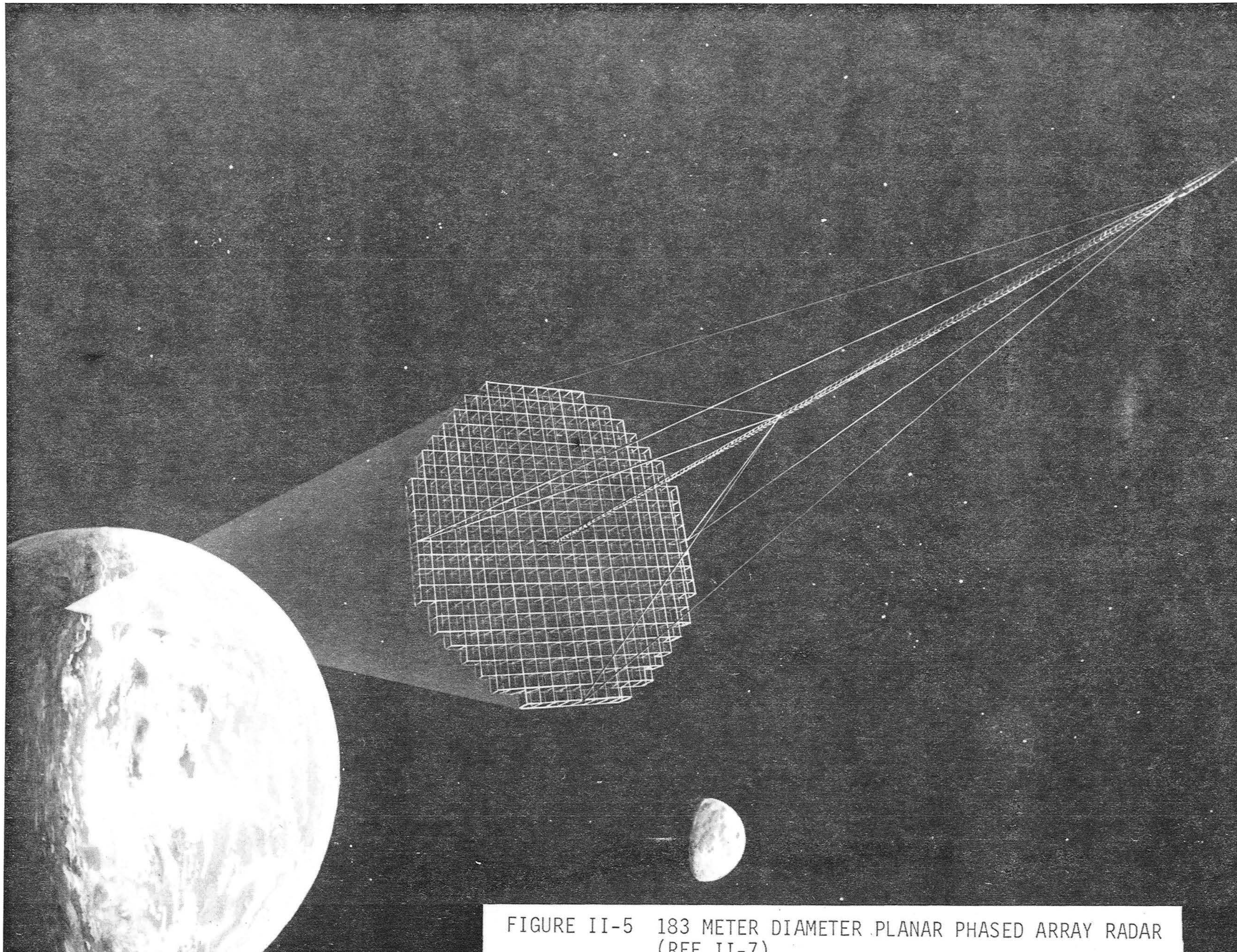


FIGURE II-5 183 METER DIAMETER PLANAR PHASED ARRAY RADAR (REF II-7)

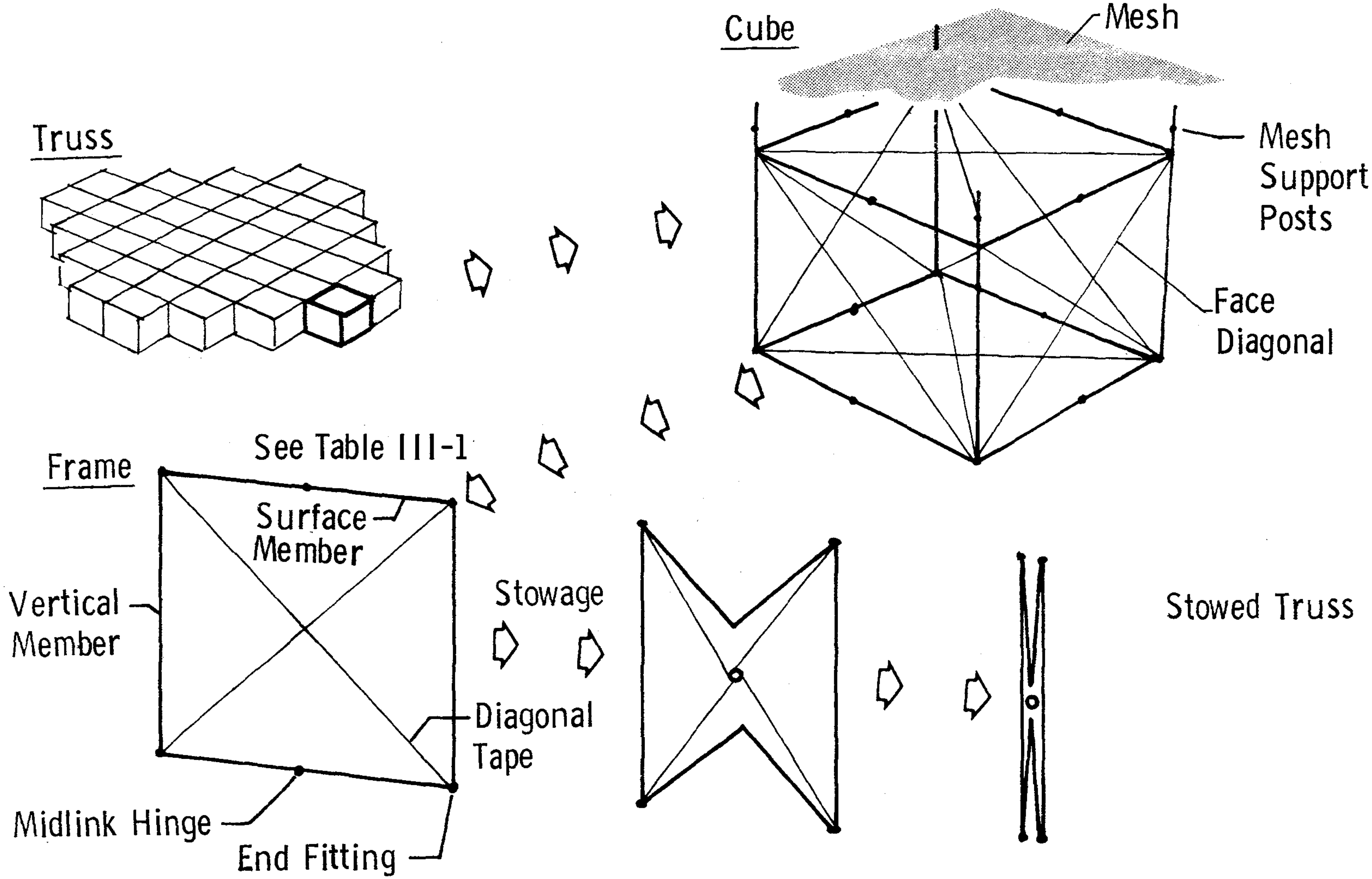


FIGURE II-6-DEPLOYABLE BOX TRUSS STRUCTURE

Prototype designs for all structural members and mechanisms have been defined. Electrically controlled, redundant deployment release latches connect each vertical member's end fitting to the neighboring stowed vertical member's end fittings. These latches provide the desired controlled release sequence. Redundant coil springs in the mid-link hinges drive the deploying structure. As each surface tube swings out to its deployed condition, a spring-loaded latch in the mid-link hinge locks the tube straight and provides the impulse necessary to tension the diagonal tapes and surface.

Deployment dynamics analyses have been made for typical cube faces throughout the deploying truss. Since boundary conditions vary from cube face to cube face, e.g., the outboard mass being accelerated by a given cube face's springs varies, the spring torque profiles are tailored to their locations in the truss. The springs are sized by three requirements: (1) with all springs operating at ten percent over nominal (energy input), the surface tubes are not overstressed; (2) with one spring out of each pair of redundant springs failed, enough energy is still available to deploy each cube face and tension its diagonal tapes and array surface; and (3) with nominal spring performance, all cube faces in a given row or column will deploy at the same rate. Typically, a row or column requires approximately 45 seconds to deploy.

Various types of antenna surfaces have been considered for large aperture spaceborne antennae. These range from simple RF reflective meshes to multi-layer phased arrays that include power distribution and subarray electronic modules. The concept for array surface stowage on the deployable box truss involves double-accordion pleating. One set of pleats is parallel to the truss column direction, and the second set, at ninety degrees to the first, parallels the rows. The small row pleats unfold as the rows are deployed, leaving the larger column pleats still folded. The latter then unfold sequentially as the column deployment steps take place.

This array folding concept, with its orthogonal fold lines, accommodates mesh surfaces easily and, more importantly, allows the surface to contain regularly-spaced, non-foldable objects such as subarray electronic modules. In the case of the planar phased array surface, these modules are located on .76 meter centers throughout the surface. The column fold lines on 1.5 meter centers and the row fold lines on .15 meter centers are located to avoid all of the modules. This concept is also applicable for support of flexible solar arrays.

The diameter range of the box truss is 30-200 meters where the actual maximum diameter is limited by the payload and stowage volume in the Orbiter. The primary mission applications are a low frequency, large diameter reflector, a planar space based radar, a planar solar array platform, and a science or communications platform (surface mass densities 0.05-0.15-0.40-3.42 Kg/m^2). The point of thrust application is at the center of the truss, perpendicular to the deployed plane.

C. Summary of LSS Concepts

Table II-3 summarizes the three LSS concepts which were selected as the baseline configurations for this study. Comparisons of the three classes are presented for diameter range, surface mass densities, point of thrust application, and applicable thrust to mass (acceleration) range.

TABLE II-3- SUMMARY OF LSS CONCEPTS

Concept	Diameter Range (M)	*Surface Mass Density (Kg/M^2)	Point of Thrust Application	T/M (g's)
Wrap Radial Rib	30-200	0.05-0.15	Hub	0.02-1.0
Hoop and Column	30-300	0.05-0.40	Aft end of mast	0.01-1.0
Expandable Box Truss	30-200	0.05-3.42	Center of Structure Normal to Plane	0.02-1.0

*Values are representative of typical missions:

0.05 for low frequency mesh type antennae
0.15 for radar antennae
0.40 for solar cell collectors
3.42 for high frequency antennae (aluminized honeycomb panels)

From these baseline configurations, parametric studies of LSS mass as a function of area and thrust-to-mass ratio were conducted for steady state and transient thrust effects.

III. THRUST AND THRUST TRANSIENT EFFECTS

The objective of this activity was to determine the effects of acceleration (thrust-to-mass) on the area and mass of the previously defined LSS concepts. In order to completely evaluate the interaction of propulsion systems and the LSS, steady-state and transient analyses were performed.

The principal activities were performed for single points of thrust application as described in Section II for the wrap radial rib, hoop and column, and expandable box truss. In addition, the effects of distributed thrust (multiple points of application) were determined for the hoop and column and expandable box truss LSS concepts.

The steady-state analysis (flow chart shown in Figure III-1) begins with the generation of structural finite element models upon which an inertial load (thrust-to-mass ratio) was applied. Structural members were sized to carry their individual loads and the nonstructural mass for mission-related equipment for each LSS concept over a range of mass, area, and thrust-to-mass ratio. To perform the steady state sizing analysis and identify the acceleration level at which the members and mass are impacted by the propulsion system thrust, a minimum member size and mass was determined.

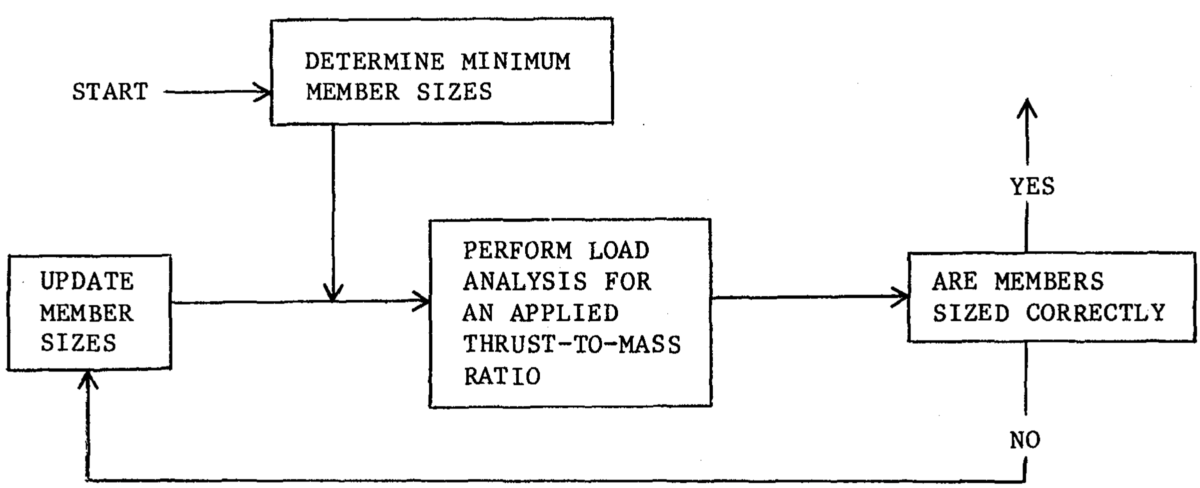


FIGURE III-1 - STEADY STATE ANALYSIS FLOW CHART

Designed as a minimum mass system, structural impacts due to acceleration forces were determined. The output of these analyses were dynamic models used for the transient thrust effects and parametric data which characterize the LSS mass and area as a function of thrust-to-mass ratio. The parametric data generated determined the effect of thrust-to-mass ratio on the LSS mass as a function of area and the effect of LSS diameter on LSS mass as a function of thrust-to-mass ratio.

The engine start and/or shutdown thrust transients on the last orbit transfer (apogee) burn can impose transient loads induced by the propulsion system to the structure, which could be greater than the steady-state loads at the burnout thrust-to-mass ratio. To complete this task, the effect of the engine thrust transients on the LSS was determined from the dynamic models upon which various engine ramp times were imposed. Displayed in Figure III-2 is the flow chart for the thrust transient effects analysis.

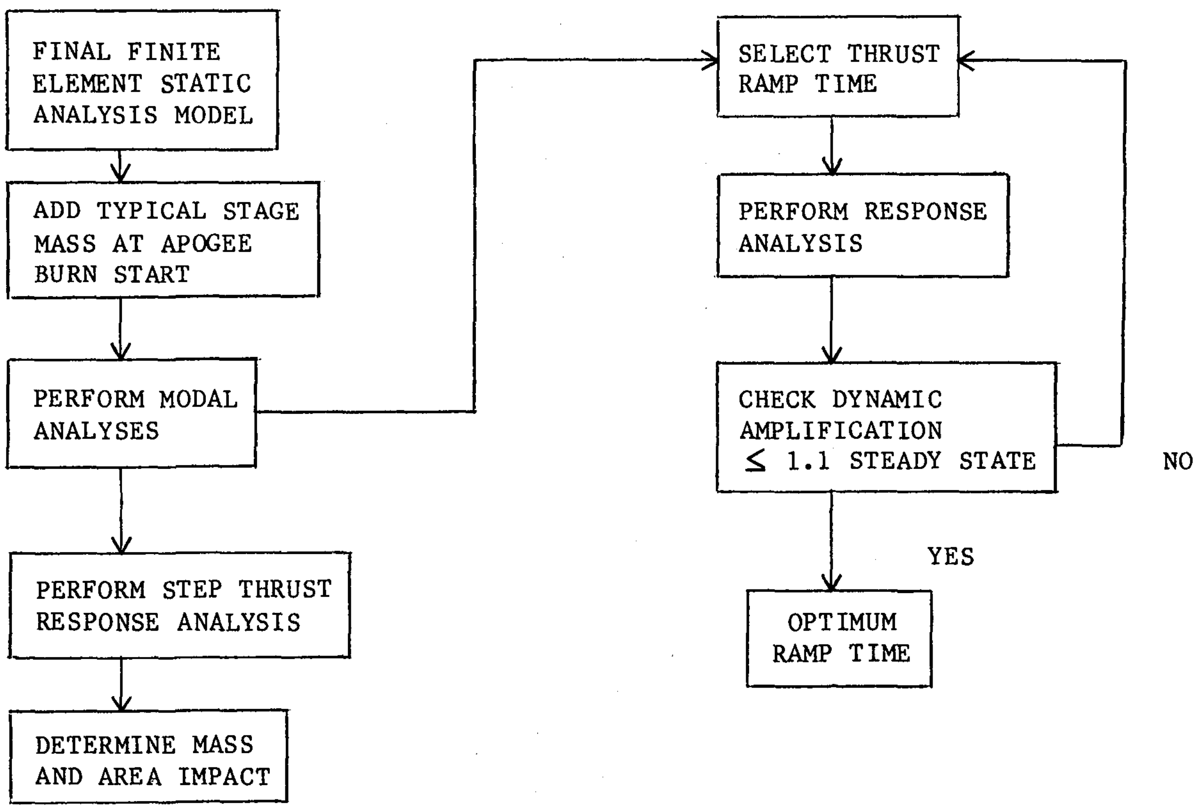


FIGURE III-2 - THRUST TRANSIENT EFFECT ANALYSIS FLOW CHART

This effort was performed under the following guidelines:

1) For single Point-Thrust application thrust assumed to vary linearly with time;
2) Transient time of thrust application variable from instantaneous loading to that time when thrust transients do not influence previous results;
3) Representative configurations were used for three LSS concepts; and
4) Results were extrapolated for the remaining configurations.

Additional results of the thrust transient analysis for multi-point thrust application to assess the effect of dispersed thrust were obtained for the expandable box truss and hoop and column. The wrap radial rib does not have the supportive structure necessary for multi-point thrust applicability. It follows that the wrap radial rib will not be discussed in the multi-point thrust section.

The previous topics will be discussed in the following sections for each Large Space System class.

A. Box Truss Analysis

1. Assumptions and Approach

An automatic model generator was used to create finite element models for both the static parametric analysis and the transient dynamic analysis.

The NASTRAN finite element model consisted of rod elements (one per member) with 3 degrees of freedom per node. A quarter segment of the LSS (Figure III-3) was modeled with symmetric load conditions. The structural mass, nonstructural mass, and fitting mass were lumped at the nodes. A 20% margin was applied to the mass of all structural members.

Fitting mass was constant, consisting of an end fitting mass per node of 1.36 kg and a surface member (see Table III-1) mid-deployment hinge mass of 0.54 kg. From previous studies, a truss depth of 8.84 meters was derived from a representative available payload length in the Orbiter cargo bay. A minimum mass system member was sized to be no smaller than 3.8 cm diameter by 0.044 cm thickness. Strength analysis of the members incorporated minimum material properties (shown in Table III-1) and a 1.5 safety factor. Allowable failure modes of the structure included Euler column and local buckling, and material yield.

The inertial loads were applied to the nodes to simulate orbit transfer. The analysis allowed one set of diagonals to go slack during transfer. It follows that the stiffness characteristics of the slack diagonals were not included in the finite element model but their mass was included. The diagonal members were sized based on a 1/6 effective axial stiffness of surface members in the cube face.

2. Box Truss Steady State Analysis

Listed in Table III-2 are those cases which were subjected to steady-state analysis.

Each finite element model was optimized for the appropriate acceleration level and surface density. The structural optimization for each acceleration level utilized members from Table III-1. Six tubular surface members and their respective six face diagonals were identified. Five cruciform vertical member sizes were identified. The surface diagonals which are on the front and back surfaces of the truss were all 0.084 cm^2 in area.

The results from the steady-state analysis are presented in Figures III-4 through III-7. Figure III-4 illustrates a representative structural

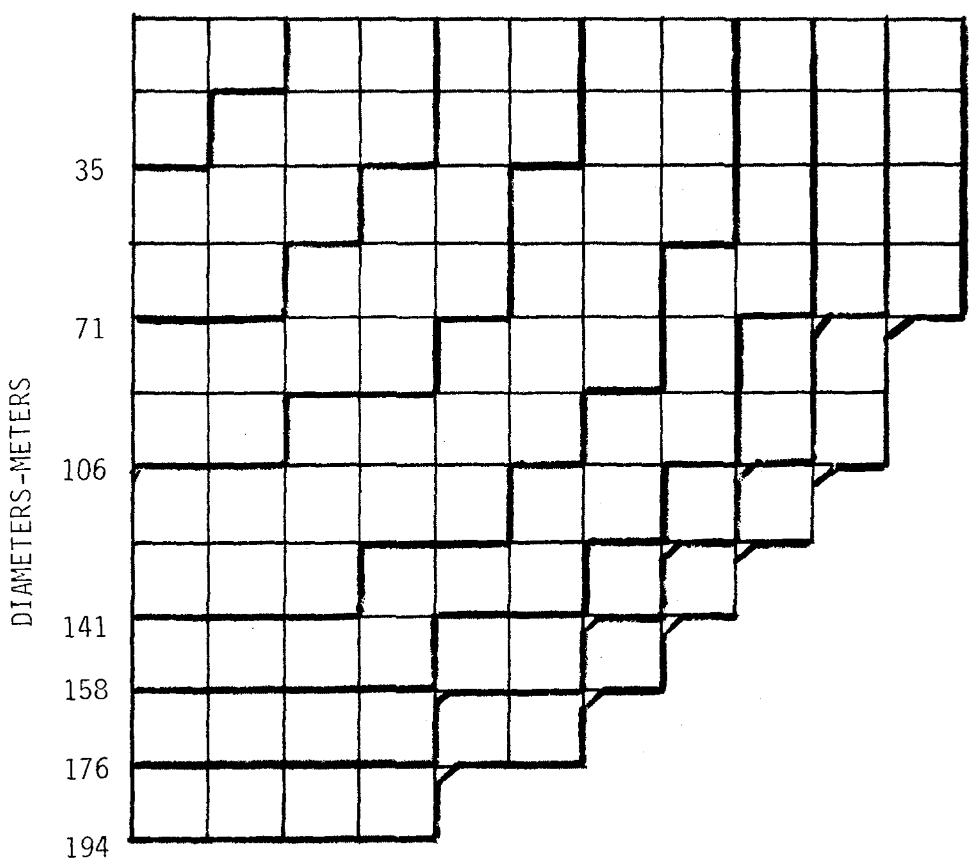
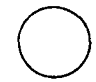
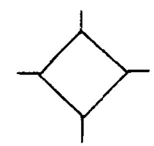


FIGURE III-3 BOX TRUSS QUARTER SEGMENT MODELS

TABLE III-1 MEMBER PROPERTIES (8.84 METER MEMBERS)

MEMBERS	DIMENSIONS (cm)	CROSS SECTION	ALLOWABLE LOADS (N)
SURFACE MEMBERS (E = 103 X 10^9 N/m^2) (ρ = 2000 Kg/m^3)			
1-	3.81 X 0.044		80
2-	5.08 X 0.044		200
3-	7.11 X 0.044		540
4-	7.11 X 0.112		1370
5-	7.11 X 0.224		2750
6-	7.11 X 0.559		6870
VERTICAL MEMBERS (E = 103 X 10^9 N/m^2) (ρ = 2000 Kg/m^3)			
	Box Section & Flanges		
A-	3.18 X 0.044 & 0.635 X 0.089		140
B-	3.18 X 0.044 & 1.905 X 0.089		390
C-	3.18 X 0.044 & 3.180 X 0.089		810
D-	3.18 X 0.140 & 3.180 X 0.279		2550
E-	3.18 X 0.351 & 3.180 X 0.701		6370

MEMBERS	AREA (cm^2)	
FACE DIAGONALS (E = 138 X 10^9 N/m^2) (ρ = 2000 Kg/m^3)		MATERIAL = ALL MEMBERS ARE GRAPHITE EPOXY
1-	0.084	
2-	0.116	
3-	0.115	
4-	0.387	
5-	0.787	
6-	1.968	
SURFACE DIAGONALS (E = 138 X 10^9 N/m^2) (ρ = 2000 Kg/m^3) A = 0.084 cm^2)		

TABLE III-2 - EXPANDABLE BOX TRUSS STEADY STATE ANALYSIS DATA POINTS

DIAMETER (m)	SURFACE DENSITY (kg/m^2)	THRUST/MASS (g's)
35	3.42	0.02; 0.05; 0.20
35	0.40	0.20; 0.80
35	0.15	0.20; 0.80
35	0.05	0.20; 0.80
71	3.42	0.02; 0.05
71	0.40	0.02; 0.05; 0.20
71	0.15	0.02; 0.05; 0.20; 0.80
71	0.05	0.02; 0.05; 0.20; 0.80
106	0.40	0.02; 0.05; 0.20; 0.40
106	0.15	0.02; 0.05; 0.20
106	0.05	0.02; 0.05; 0.20; 0.80
141	0.15	0.02; 0.05; 0.20
141	0.05	0.02; 0.05; 0.20; 0.40
158	0.15	0.02; 0.05
158	0.05	0.02; 0.05; 0.10
176	0.05	0.02; 0.05
194	0.05	0.02

mass versus maximum acceleration curve for a 71 m diameter box truss with surface density as a parameter. Structural mass is defined as the mass of structure needed to support itself and the surface payload. All combinations of diameter and surface mass exhibit a common trend-exponential increase in system mass as a function of T/M after the mass is affected by acceleration level causing member size to exceed minimum gage. Figures similar to Figure III-4 were used to derive Figure III-5, structural unit mass versus maximum acceleration. Figure III-5 summarizes the effect of acceleration on the structural mass required relative to the minimum structural system. It is important to realize that each structure type and diameter are unique in terms of minimum mass size. The parametric curves presented in Figure III-5 are mass normalized and are not valid when comparing different diameter mass impacts (this statement also applies to Figures III-14 and III-15 for the wrap radial rib and Figure III-22 for the hoop and column). It can be seen that the larger the diameter and the heavier the surface, the greater the acceleration impact on structural mass. An acceleration of 0.05 g's has minimal effect on structural mass. However, at 0.2 g's, the impact ranges from 20% to 100%. Therefore, based only on impact on box truss structural mass, the optimum T/M varies from 0.05 to 0.20 g's over the range of diameters considered in this study. Shown in Figure III-6 is system mass versus maximum acceleration. System mass is defined as the total mass of the LSS including structure and surface. Above 0.2 g's, drastic increases in system mass exist. Figure III-7 presents system mass versus diameter for variable surface density and acceleration for all box truss systems analyzed.

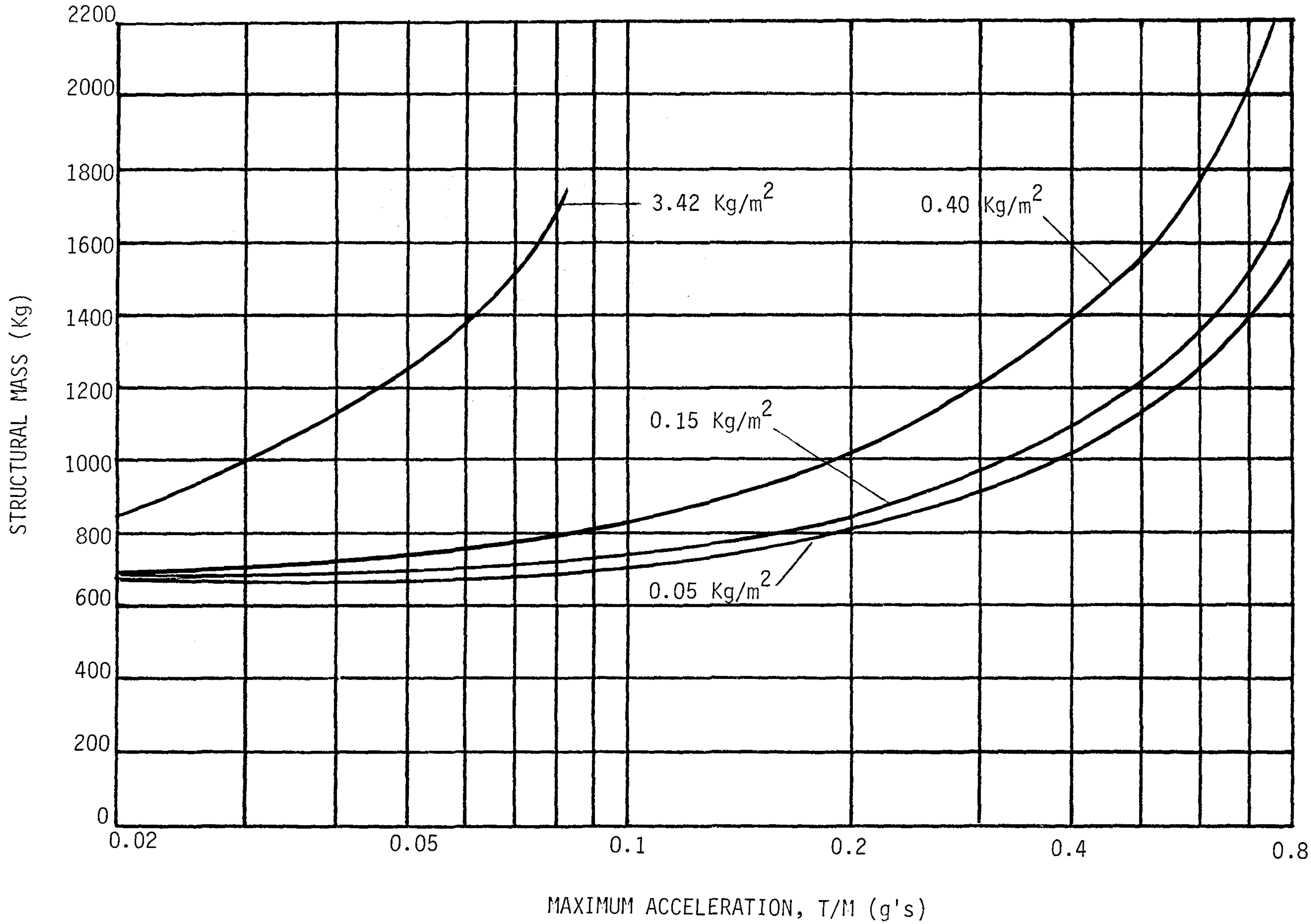


FIGURE III-4 STRUCTURAL MASS IMPACT FOR 71 METER (BOX TRUSS)

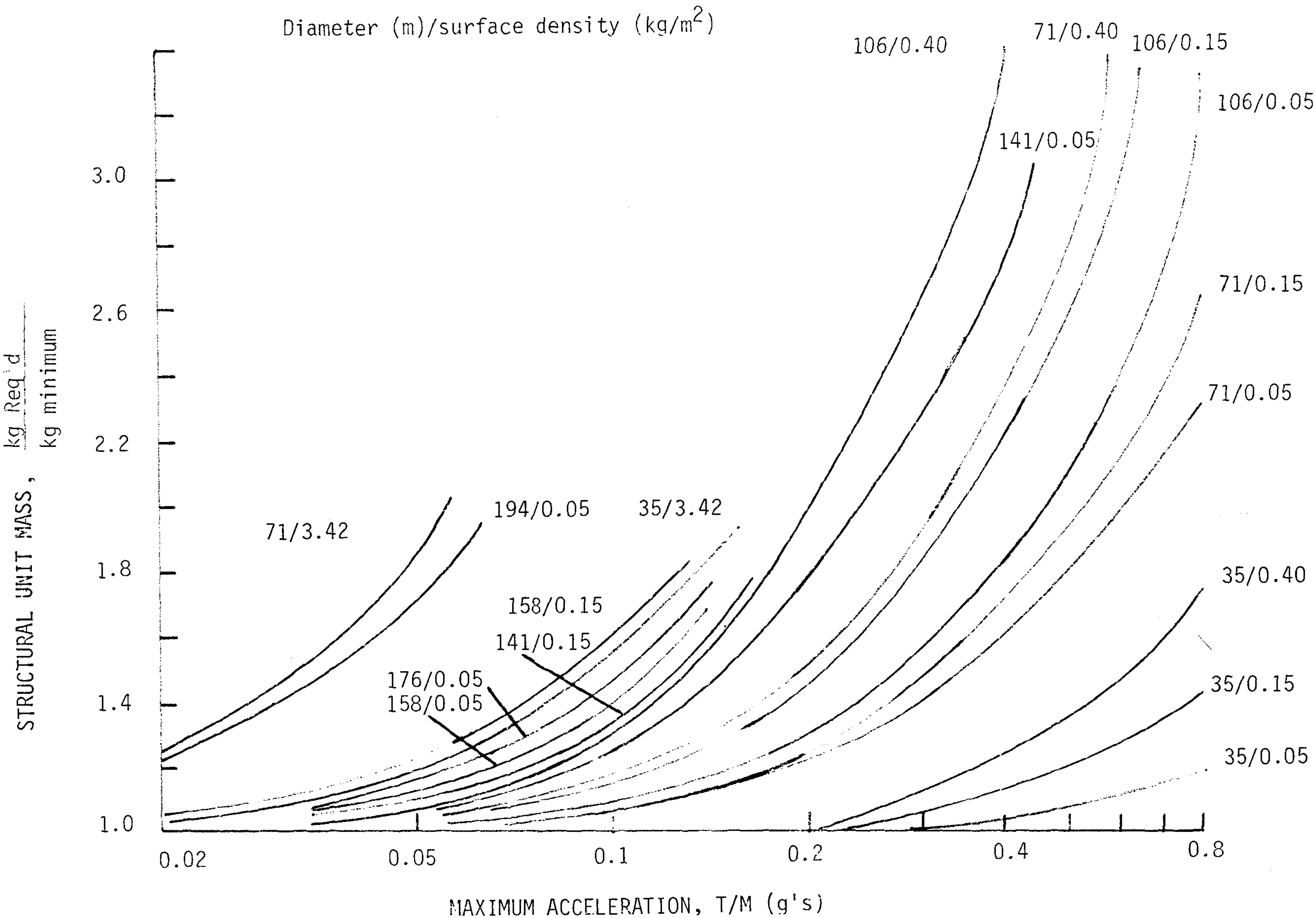


FIGURE III-5- UNIT MASS VERSUS MAXIMUM ACCELERATION (BOX TRUSS)

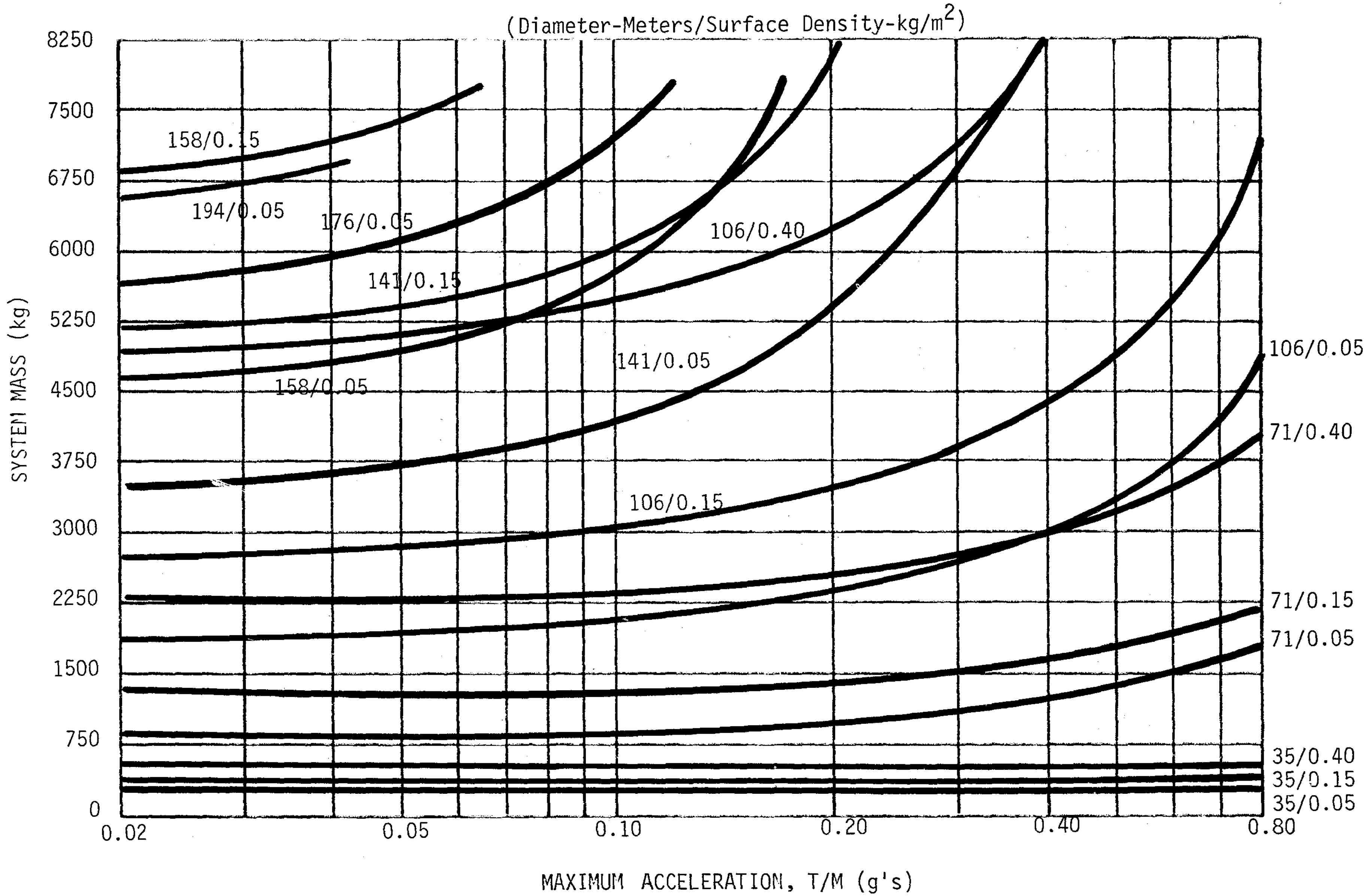


FIGURE III-6- BOX TRUSS SYSTEM MASS VERSUS ACCELERATION

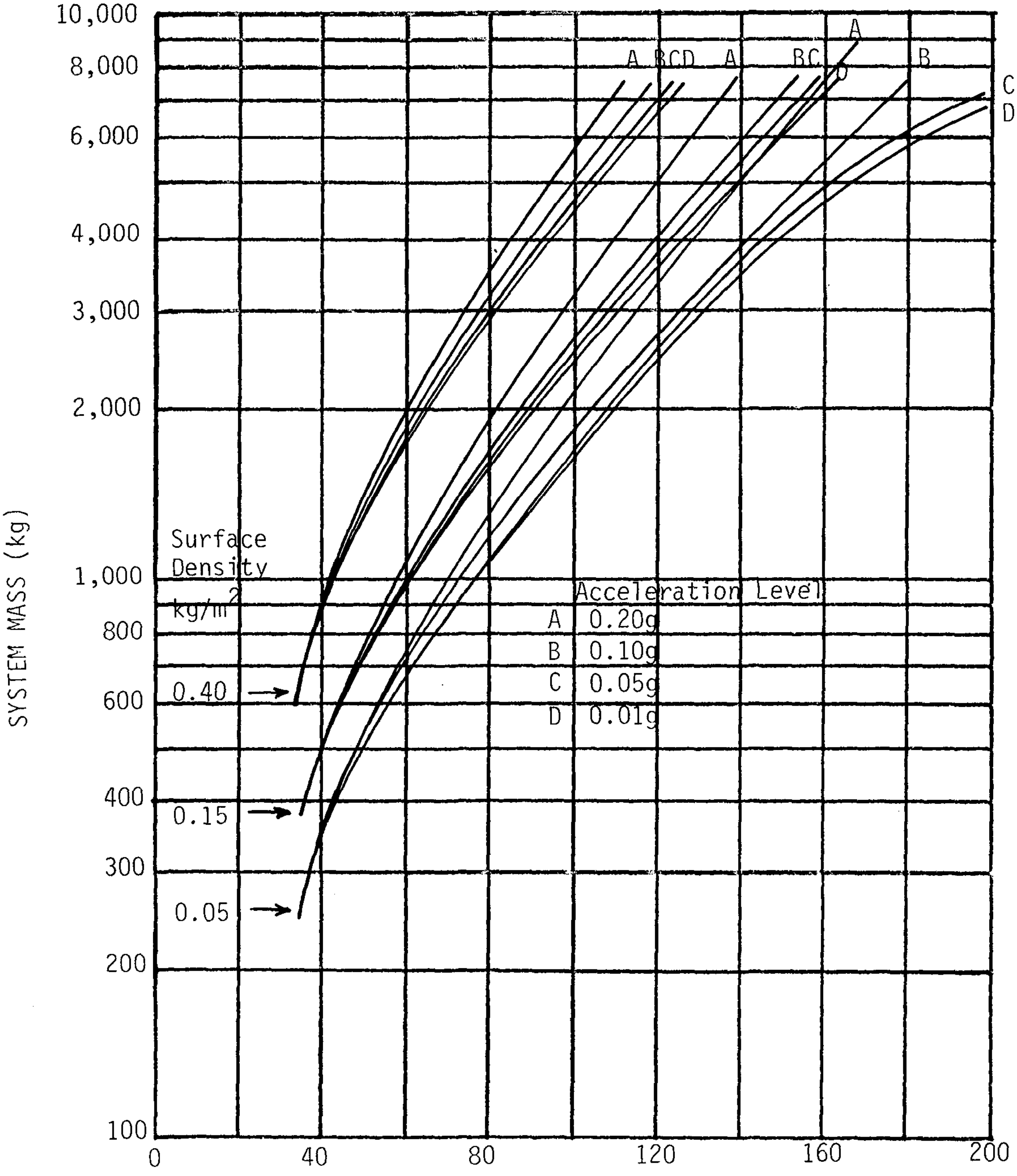


FIGURE III-7- EXPANDABLE BOX TRUSS SYSTEM MASS VERSUS DIAMETER

3. Box Truss Transient Thrust Effect

Transient dynamic finite element analyses were performed on four configurations thought to be representative of the range of designs under consideration. The maximum dynamic amplification factor was obtained for each member in a given design by ratioing the maximum transient load observed in a member during engine startup to the steady state load in the same member obtained from a static (inertial relief) analysis. It was impossible to select a single location of structural member upon which a capable critical design parameter could be based. Therefore, it was not possible to select an explicit design load amplication factor from the data. Instead, a probablistic mean dynamic amplification factor was chosen for each dynamic model at a given ramp time (T_R) and applied to member loads computed from static models. The equivalent static loads thus obtained were used to resize members and assess the effect of dynamic loads on structural mass for the full range of configurations under consideration.

When performing a response analysis, the mode shapes and frequencies of the system being investigated were calculated, and then the desired thrust profile was applied to that modal model. The principal problem arose in defining the realistic modal characteristics of the system. To obtain a realistic dynamic model of the LSS and OTV that are being accelerated by the thrust, the mass of the OTV should be included. Unfortunately, this mass varies depending on the OTV characteristics.

Three sample dynamic cases were run to determine the effect of OTV mass on the modes. Case 1 was free modes with no stage mass. Case 2 was free modes with a typical OTV. Case 3 was fixed modes which is equivalent to an infinite OTV mass. The fundamental frequencies are:

Case 1: 6.44 Hz (no OTV, Free)
Case 2: 4.88 Hz (with OTV)
Case 3: 3.71 Hz (fixed)

As can be seen, the frequencies do vary, and it is necessary that a typical OTV mass be included. Case 2 with an actual OTV mass is the realistic case. However, OTV masses are not known apriori. Therefore, a typical stage mass of 7940 Kg consistent with the Task III results was selected. Using these modes, response analyses were performed to determine the amplification factors for a step response and the optimum thrust for minimum amplification.

The objective is to relate the results of the detailed response analysis to the other cases. To accomplish this, it must be shown that the single degree of freedom relationship $T_R = 1/f$ (f = frequency) applies to the multi-degree of freedom systems. Then the optimum T_R can be defined as a function of the fundamental frequency.

Box truss configurations chosen for transient dynamic analysis are shown in Table III-3. Each of the small trusses were analyzed for $T_R = 0/3f_1$ (STEP), $1/3f_1$, $2/3f_1$, $3/3f_1$, $4/3f_1$ while the larger two trusses were analyzed for $0/3f_1$, $1/3f_1$ and $3/3f_1$ only. The first nine natural frequencies for each design are shown in Table III-4. Typical results of the dynamic analyses are displayed as maximum dynamic amplification factors for the bottom surface horizontal and vertical members of the truss in Figures III-8 and III-9. Note that although the general trend indicates dynamic amplification factors increase with distance from the center of the truss, the

TABLE III-3 -TRANSIENT ANALYSIS CASES FOR BOX TRUSS

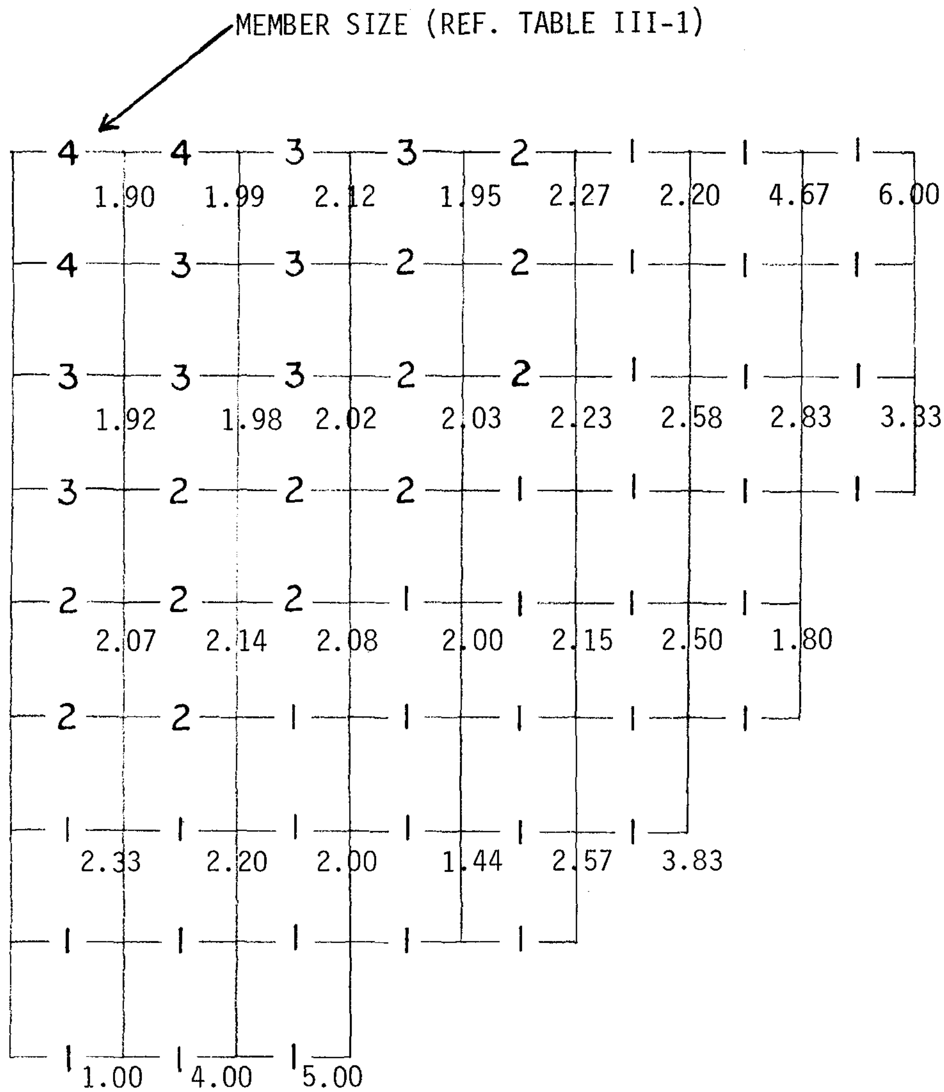
CONFIGURATION NAME	ALLOWABLE STEADY STATE g's	DIAMETER (METERS)	SURFACE DENSITY Kg/m2
BT505	.05	35	3.42
BT507	.60	35	3.42
BT206	.20	141	0.15
BT202B	.05	141	0.15

TABLE III-4 - BOX TRUSS STRUCTURAL FREQUENCIES

CONFIGURATION	NATURAL FREQUENCIES (Hz)								
NAME Mode	1	2	3	4	5	6	7	8	9
BT505	4.55	6.07	8.28	9.46	9.91	12.1	14.2	20.1	20.2
BT507	1.19	2.68	3.90	4.12	4.75	6.21	6.46	6.50	7.42
BT206	1.82	2.39	4.43	4.92	7.47	9.03	9.30	9.97	11.3
BT202B	1.03	1.66	3.45	3.96	6.56	7.64	8.30	9.11	9.90

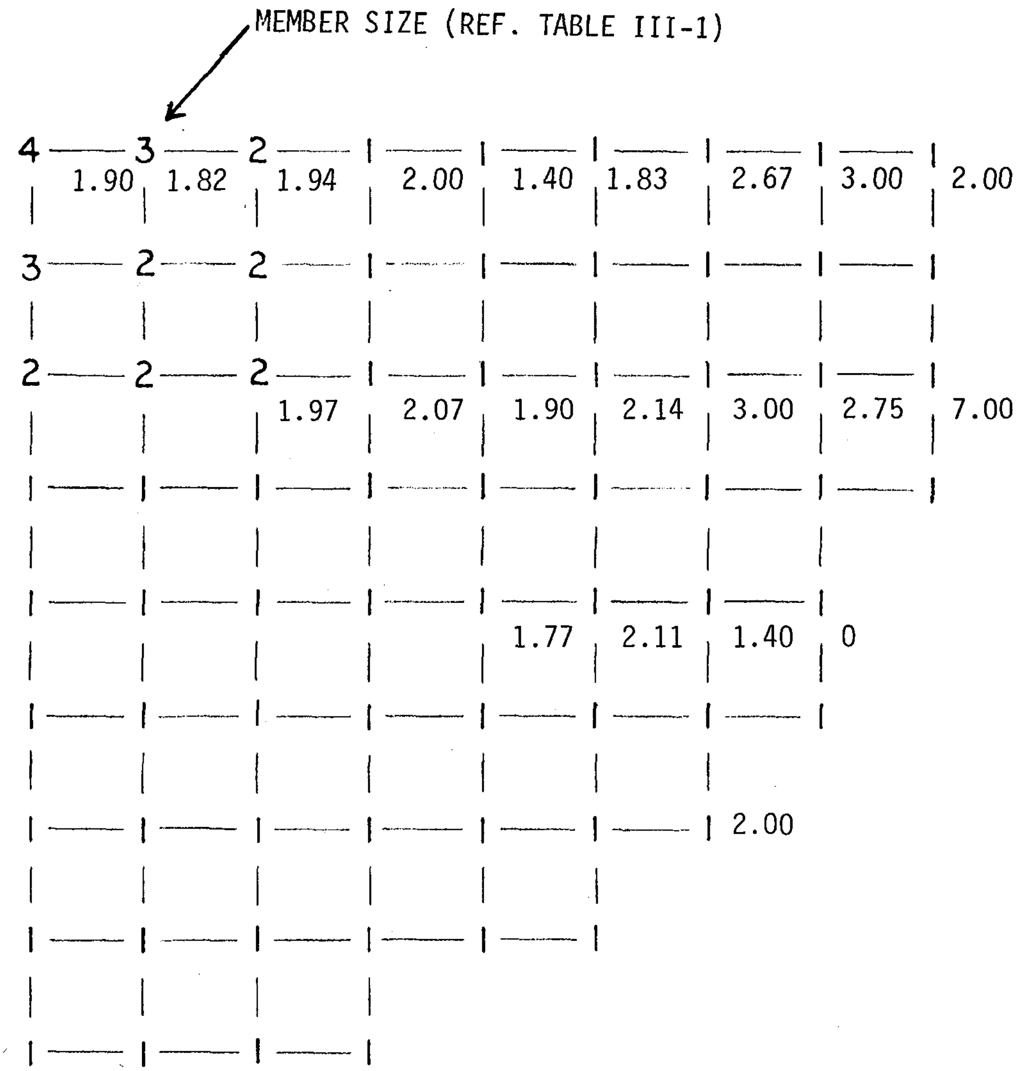
factors for the larger trusses do not increase monotonically. This appears to be due to high accelerations present at the periphery of the structure as illustrated in Figure III-10. Since this "end whip" is dependent upon the superposing of vibratory modes of the structure and, in general, is present to differing degrees in every truss, an attempt to obtain a single representative dynamic amplification was not straightforward.

The probalistic distributions for maximum dynamic amplification factors for configurations BT 505 and BT 507 are shown in Figure III-11. As a first approximation, probablistic mean values were chosen for each configuration at each T_R. These means are plotted as a function of T_R in Figure III-12. From this curve, a value of 2.05 was chosen as an approximate dynamic amplification factor for $T_R = 0/3f_1$ and applied to the results of box truss static analyses to determine the effect of transient thrust on structural mass.



- o Surface Members
- o Diameter = 141m
- o Surface Density = $0.15 kg/m^2$
- o T/M = 0.05g
- o T_R = Step

FIGURE III-8 TYPICAL DYNAMIC AMPLIFICATION FACTORS FOR SURFACE TUBES



o Symmetric about 45^{o} line
o Vertical Members
o Diameter = 141m
o Surface Density = 0.15kg/m^2
o T/M = 0.05g
o T_R = Step

FIGURE III-9 TYPICAL DYNAMIC AMPLIFICATION FACTORS FOR VERTICAL MEMBERS

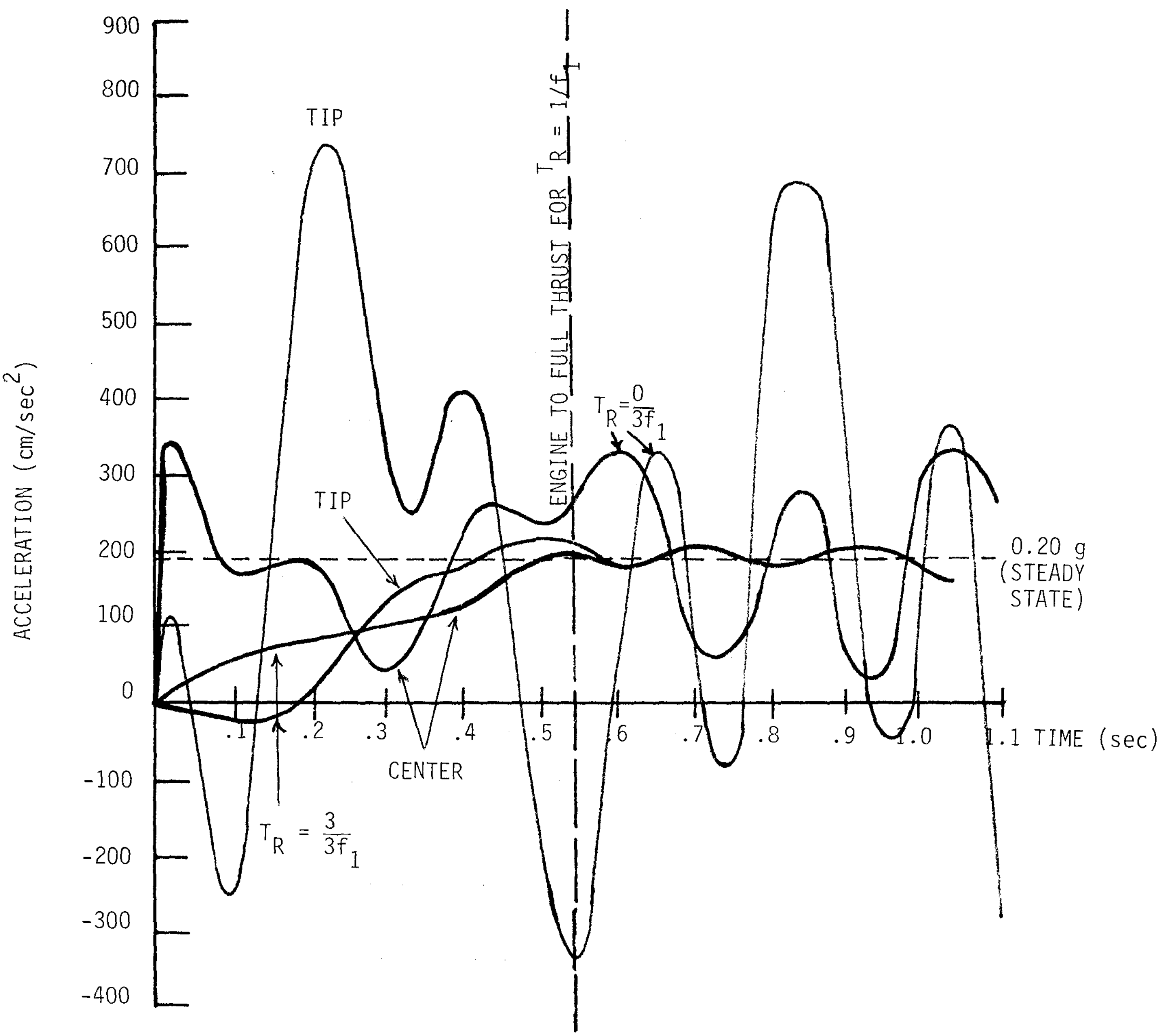
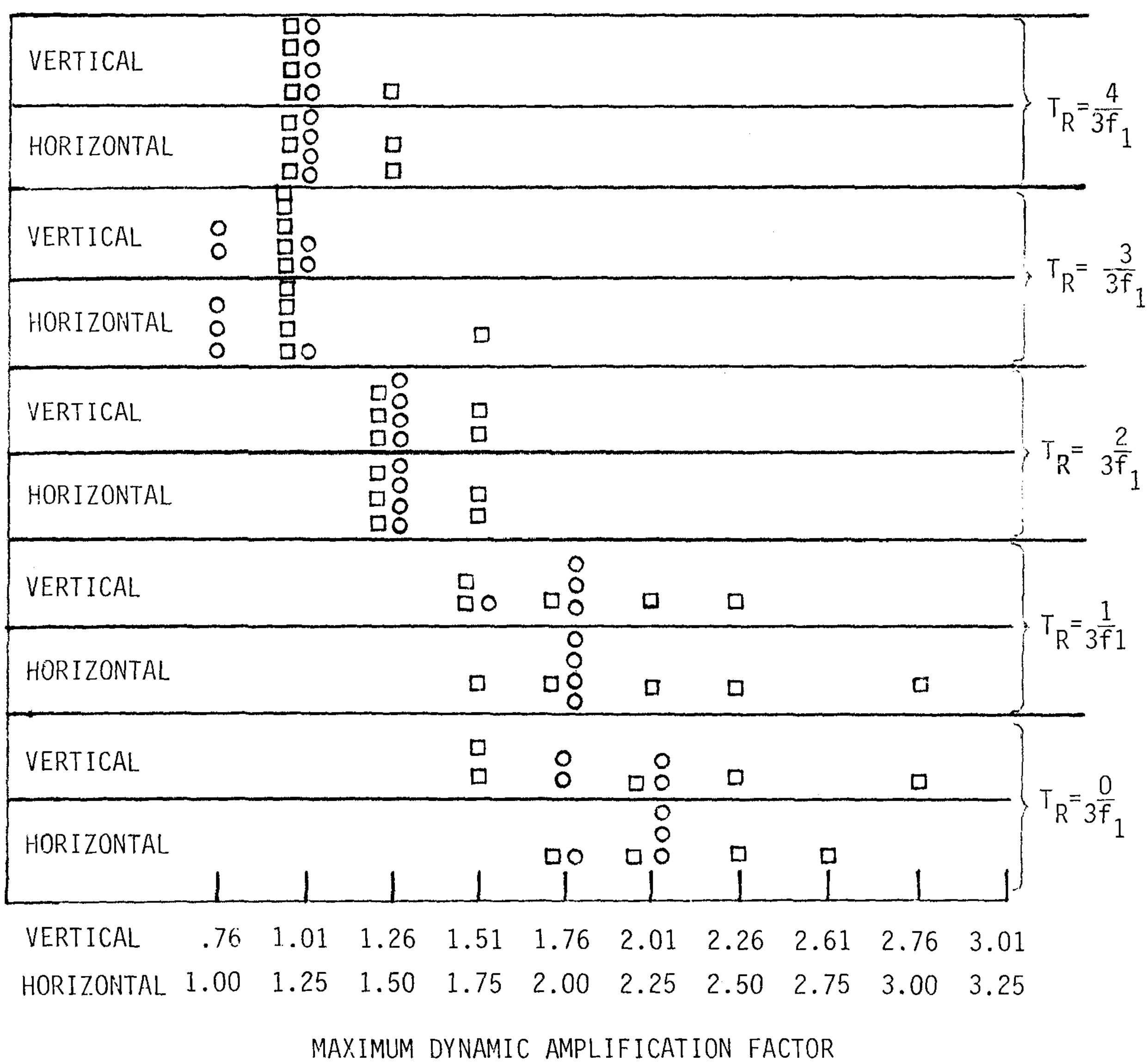


FIGURE III-10 ACCELERATIONS FOR 141m DIAMETER, 0.15 kg/m^2, BOX TRUSS-CENTER AND TIP LOCATIONS FOR $T_R = \frac{0}{3f_1}$, AND $\frac{3}{3f_1}$, (0.20g)

FIGURE III-11 PROBABILITY DISTRIBUTION OF DYNAMIC AMPLIFICATION FOR BOX TRUSS

□ CONFIGURATION BT505

○ CONFIGURATION BT507



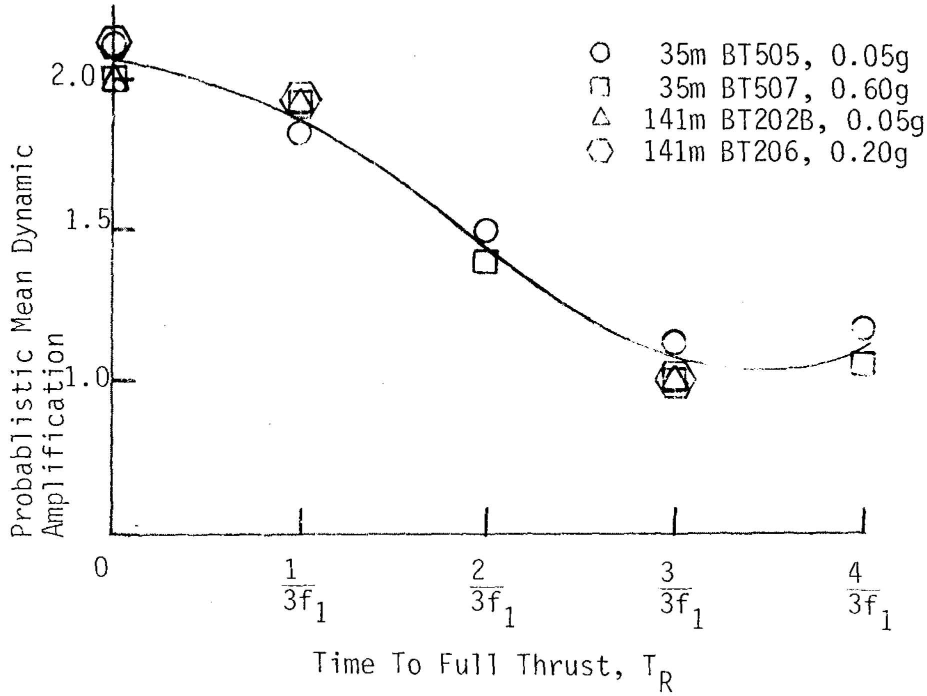


FIGURE III-12 BOX TRUSS MEAN DYNAMIC AMPLIFICATION

To determine the actual design load factors for the structural sizing during a constant thrust burn strategy, the dynamic amplification factors are multiplied by the actual T/M value at the start of the apogee burn. This point of the orbit transfer is the critical dynamic time since the system mass is the lowest of all burn starts. To determine the ratio of T/M at start of apogee burn to T/M at maximum steady-state, typical system masses at start and end of apogee burn were derived from Task III. By ratioing these masses, the ratio of T/M can be derived. Table III-5 presents those results. The T/M derived for the start of apogee burn is multiplied by the dynamic amplification factors and compared to the steady-state design T/M at burnout to determine the maximum design loading factor. Table III-6 presents a summary of the design load calculations for a T/M of 0.05 g's and the transient load impact for the box truss.

The structural analysis approach to the shutdown transient effect used the following thrust/time scenario. At initation of burn, the thrust is linearly increased from zero to a value corresponding to the maximum steady state acceleration in a time interval equal to the fundamental period. The thrust is maintained for an arbitrarily long interval to allow transients to attenuate. Finally, to simulate engine shutdown, the thrust was instantaneously set to zero. The results showed higher accelerations and hence, higher loads at the structure periphery than at the center. Although these loads are higher than those observed at steady state, they are lower than those observed for an abrupt engine start-up. The mass impact for shutdown was less than 2%.

TABLE III-5 - MASS, THRUST, AND T/M FOR TYPICAL STAGE

THRUST (N)	THRUST-TO-MASS T/M APOGEE SHUTDOWN MASS = 9750 kg T/M (MAX)	THRUST-TO-MASS T/M START OF APOGEE BURN MASS = 14500 kg T/M START*
1870	0.02	0.0134
4670	0.05	0.0334
18680	0.20	0.134
37360	0.40	0.268
74730	0.80	0.536

*Assumes ratio of mass at start of apogee burn to mass at apogee burn shutdown remains approximately constant for various thrust values:

$$\frac{M_{shutdown}}{M_{start}} = 0.67$$

From the Task III results, this ratio was constant for initial accelerations from 0.003 to 0.010g for either constant thrust or constant acceleration cases and an Isp of 450 seconds.

TABLE III-6 - BOX TRUSS DESIGN TRANSIENT THRUST IMPACT- CONSTANT THRUST BURN

T_R	DESIGN AMPLIFICATION X 0.034 g's	STEADY STATE DESIGN T/M	DESIGN LOAD FACTOR	ACTUAL DESIGN LOAD AMPLIFICATIONS*	AVERAGE TRANSIENT Kg REQ'D / Kg STEADY STATE
STEP	2.05 X 0.034 = 0.070 g's	0.05 g's	0.070 g's	1.40	1.10
$1/3f_1$	1.85 X 0.034 = 0.063 g's	0.05 g's	0.063 g's	1.26	1.03
$2/3f_1$	1.45 X 0.034 = 0.049 g's	0.05 g's	0.050 g's	1.00	1.0
$3/3f_1$	1.05 X 0.034 = 0.036 g's	0.05 g's	0.050 g's	1.00	1.0
$4/3f_1$	1.15 X 0.034 = 0.039 g's	0.05 g's	0.050 g's	1.00	1.0

$$*\text{AMPLIFICATION} = \frac{\text{DESIGN LOAD FACTOR}}{\text{STEADY STATE DESIGN T/M,}}$$ APPROPRIATE FOR ALL T/M RANGES

<u>NOTE</u>: FOR THE BOX TRUSSES STUDIED, RAMP TIMES OF T_R = 0.2 TO 2 SECONDS @ $T_R = 2/3f_1$ PRODUCE NO STRUCTURAL IMPACT

4. Box Truss Summary and Conclusions

Seventeen typical box truss configurations with diameters ranging from 35 to 194 m and surface densities ranging from 0.05 to 3.42 kg/m^2 were analyzed to determine the effect of steady state thrust on structural mass. At a typical low-thrust T/M ratio of 0.05 g's the structural mass impact was relatively small (20% or less) for fifteen of the seventeen cases. Exceptions were the maximum diameter (194 m/0.05 kg/m^2) and the maximum surface density (71 m/3.42 kg/m^2) cases where the structural mass impacts were 70% and 90% respectively. Each of the configurations exhibited a common trend after the minimum gage structural mass was affected by acceleration, i.e. an exponential increase in structural mass as T/M was increased. For a given diameter and surface density, the mass change is relatively small over a wide rage of T/M and, with the exception of the largest diameter and highest surface density cases noted above, only small reductions in structural mass are realized at T/M ratios below 0.05 g's.

Four typical box truss configurations were analyzed to determine the effect of start and shutdown transients on structural mass. These analyses were conducted for a constant thrust burn strategy. Mean dynamic amplification factors for start transients varied from 2.05 for a step thrust input to 1.05 for a thrust ramp equal in time to the period of the fundamental frequency of the combined LSS-OTV system. For a constant thrust burn strategy. The most critical start condition from a dynamic standpoint is the apogee burn. Anaysis at this condition indicated an average structural mass impact (relative to steady state) of 10% for a step thrust input and negligible mass impact for ramps equal in time to 2/3 of the fundamental frequency. For all configuraitons considered, start times which produced negligible impact ranged from 0.2 seconds to 2.0 seconds. Shutdown transient analyses indicated that the structural mass impact for an instantaneous thrust cutoff at the end of the apogee burn was less than 2%.

C. Wrap Radial Rib

1. Assumptions and Approach

For the wrap radial rib concept, data were received from Lockheed which provided the structural characteristics for their nominal configurations. Parametric data were also provided which related deployed stiffness to mass and packaging efficiency. From these provided data, the steady state thrust effects on system mass were determined.

The baseline design for the wrap radial rib is a Lockheed 100 meter diameter system with 96 ribs. The number of ribs for other diameters was selected to be proportional to $\sqrt{\frac{100m}{\text{diameter}}}$ X 96 ribs. The rib size was selected to maintain a tip deflection for mesh tension that is proportional to diameter ($\delta_{TIP} \propto$ diameter/100 m). This proportionality was based on the general requirements that as the antenna diameter increases, typically the antenna operating frequency decreases and, therefore, surface accuracy requirements are less. The rib properties used in the analysis are shown in Table III-7. The mass values of all systems include a 5% factor for the hub. The oval rib cross section was used instead of the Lockheed flex rib shape, shown in Figure III-13, for ease of analysis.

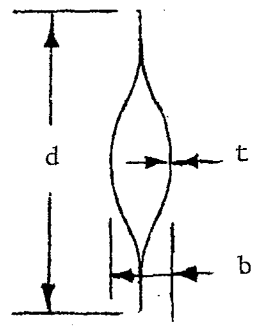
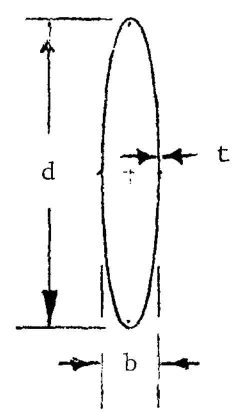


FIGURE III-13 - FLEX RIB CROSS SECTION

TABLE III-7 - RIB PROPERTIES



- GRAPHITE EPOXY MATERIAL
- OVAL RIB CROSS SECTION
- RIB CROSS SECTION d/b = 5
- RIB ROOT TO TIP TAPER = 3/1
- RIB CROSS SECTION d/t = 800
- TIP DEFLECTION $\propto$ (DIAMETER) THEREFORE (d, b, t) $\propto \left(\frac{\text{DIAMETER}}{\text{100M}}\right)^{.75}$
- BASELINE IS 100 METERS @ 96 RIBS
- FAILURE STRESS = 0.6 γ E ($^t/d$) (LOCAL CRIPPLING)

  WHERE γ = KNOCK DOWN FACTOR AND E = MODULUS OF ELASTICITY
- ALLOWABLE STRESS= FAILURE STRESS/1.5 = 3.0×10^7 N/m^2

However, the data are believed to be representative of the actual flex rib cross-section configuration.

2. Wrap Radial Rib Steady State Analysis

Tables III-8 and III-9 present the results of the radial rib analyses. The data presented are for a lens-type and mesh system with surface densities of 0.15 kg/m^2 and 0.05 kg/m^2, respectively. Figures III-14 and III-15 present, in graphical form, the results of the steady-state analysis for 0.05 kg/m^2 and 0.15 kg/m^2 respectively. It can be seen that the rib is highly sensitive to acceleration level. The structural mass increases dramatically when the rib is sized for the inertial loads. The rib is not as efficient as a deep truss for carrying the combined mass of surface and its own structural mass. However, the rib has greater allowable acceleration at large diameters due to stiffness criteria that increases member sizes with diameter. Figure III-16 displays system mass versus diameter for surface densities of 0.15 kg/m^2 and 0.05 kg/m^2, respectively.

3. Wrap Radial Rib Transient Thrust Effect

To obtain the effect on structural mass of varying engine thrust rise times, transient dynamic analyses were performed on four representative LSS configurations. The five ramp times identified for the analysis are T_R = $0/3f_1$,$1/3f_1$, $2/3f_1$, $3/3f_1$, and $4/3f_1$. These analyses were performed for the following cases: diameter = 106 meters and surface = 0.05 kg/m^2; diameter = 106 meters and surface = 0.15 kg/m^2; diameter = 176 meters and surface = 0.05 kg/m^2; diameter = 176 meters and surface = 0.15 kg/m^2. Table III-10 presents the first five modes of the free-free system including a 7940 kg stage mass, which is typical of the start-up for the final apogee burn. Figures III-17 and III-18 show typical accelerations at the root and tip of a radial rib. It can be seen that for $T_R = 3/3f_1$, there is no significant amplification. For a T_R = STEP, there is significant amplification. This amplification is higher at the tip than at the root due to a whipping action that was also observed for the box truss.

From these transient analyses the bending moment distribution and dynamic amplification along the rib were derived. Although the amplification is higher at the tip, the root of the rib is the point of critical stress. Figure III-19 presents the dynamic stress versus the allowable stress along the rib. As can be seen, the dynamic stress is decreasing with radial position along rib and the allowable stress is increasing. Therefore, the root dynamic amplification factor is the design criteria. Table III-11 is a summary of these critical amplification factors for the four cases and five T_R's. Figure III-20 is a plot of the amplification factor for ramp times from T_R = STEP to $T_R = 4/3f_1$. There is a definite minimum of $T_R = 3/3f_1$, which is identical to the single degree of freedom system. However, the final criterion is the effect on structural mass, and that curve will be the factor for determining the optimum T_R.

The effect on structural mass will be determined by the actual design load factor for the structural sizing. Table III-12 presents these results. Figure III-20 is now modified to represent the actual design load amplification factor to be applied to the steady-state structural design for all radial rib cases (Figure III-21). Table III-12 presents a summary of the average structural mass effect for all radial rib configurations.

TABLE III-8 - RADIAL RIB ANALYSIS RESULTS - SURFACE DENSITY = 0.15 Kg/m^2

Case	DIAMETER METERS	No. of Ribs	THRUST/ MASS g's	MINIMUM* RIB SIZE (cm.) d	b	t	LOADED RIB SIZE (cm.) d	b	t	MASS Kg
1	35	168	0.20	22.1	4.4	0.028	22.1	4.4	0.028	670
2	35	168	0.60	22.1	4.4	0.028	36.9	7.4	0.046	1560
3	71	118	0.05	37.6	7.5	0.047	37.6	7.5	0.047	2730
4	71	118	0.17	37.6	7.5	0.047	44.8	9.0	0.056	3510
5	71	118	0.60	37.6	7.5	0.047	98.8	19.7	0.123	15240
6	106	96	0.02	50.8	10.2	0.064	50.8	10.2	0.064	6170
7	106	96	0.05	50.8	10.2	0.064	50.8	10.2	0.064	6170
8	106	96	0.17	50.8	10.2	0.064	74.2	14.8	0.093	11200
9	106	96	0.60	50.8	10.2	0.064	192.1	38.4	0.240	68960
10	141	84	0.02	62.9	12.6	0.079	62.9	12.6	0.079	10820
11	141	84	0.05	62.9	12.6	0.079	62.9	12.6	0.079	10820
12	141	84	0.17	62.9	12.6	0.079	110.0	22.0	0.137	27750
13	158	78	0.02	68.5	13.7	0.086	68.5	13.7	0.086	13490
14	158	78	0.05	68.5	13.7	0.086	68.5	13.7	0.086	13490
15	158	78	0.17	68.5	13.7	0.086	131.1	26.2	0.164	40980
16	176	74	0.02	74.3	14.9	0.093	74.3	14.9	0.093	16730
17	176	74	0.047	74.3	14.9	0.093	74.3	14.9	0.093	16730
18	194	70	0.02	79.9	16.0	0.100	79.9	16.0	0.100	20140

NOTES: *RIB SIZE AT ROOT b = RIB MINOR AXIS d = RIB MAJOR AXIS t = RIB THICKNESS

TABLE III-9 - RADIAL RIB ANALYSIS RESULTS - SURFACE DENSITY = 0.05 Kg/m^2

CASE	DIAMETER METERS	NO. OF RIBS	THRUST/ MASS g's	MINIMUM* RIB SIZE (cm.) d	b	t	LOADED RIB SIZE (cm.) d	b	t	MASS Kg
1	35	168	0.20	22.1	4.4	.028	22.1	4.4	.028	560
2	35	168	0.60	22.1	4.4	.028	28.3	5.7	.035	880
3	71	118	0.05	37.6	7.5	.047	37.6	7.5	.047	2290
4	71	118	0.20	37.6	7.5	.047	37.6	7.5	.047	2290
5	71	118	0.60	37.6	7.5	.047	84.7	16.9	.106	11030
6	106	96	0.02	50.8	10.2	.064	50.8	10.2	.064	5190
7	106	96	0.05	50.8	10.2	.064	50.8	10.2	.064	5190
8	106	96	0.17	50.8	10.2	.064	58.3	11.7	.073	7000
9	106	96	0.60	50.8	10.2	.064	175.6	35.0	.219	57330
10	141	84	0.02	62.9	12.6	.079	62.9	12.6	.079	9110
11	141	84	0.05	62.9	12.6	.079	62.9	12.6	.079	9110
12	141	84	0.17	62.9	12.6	.079	90.4	18.0	.113	18120
13	158	78	0.02	68.5	13.7	.086	68.5	13.7	.086	11340
14	158	78	0.05	68.5	13.7	.086	68.5	13.7	.086	11340
15	158	78	0.17	68.5	13.7	.086	110.1	22.0	.138	27990
16	176	74	0.02	74.3	14.9	.093	74.3	15.0	.093	14050
17	176	74	0.05	74.3	14.9	.093	74.3	15.0	.093	14050
18	194	70	0.02	79.9	16.0	.100	79.9	16.0	.100	16890

NOTES: *RIB SIZE AT ROOT b = RIB MINOR AXIS d = RIB MAJOR AXIS t = RIB THICKNESS

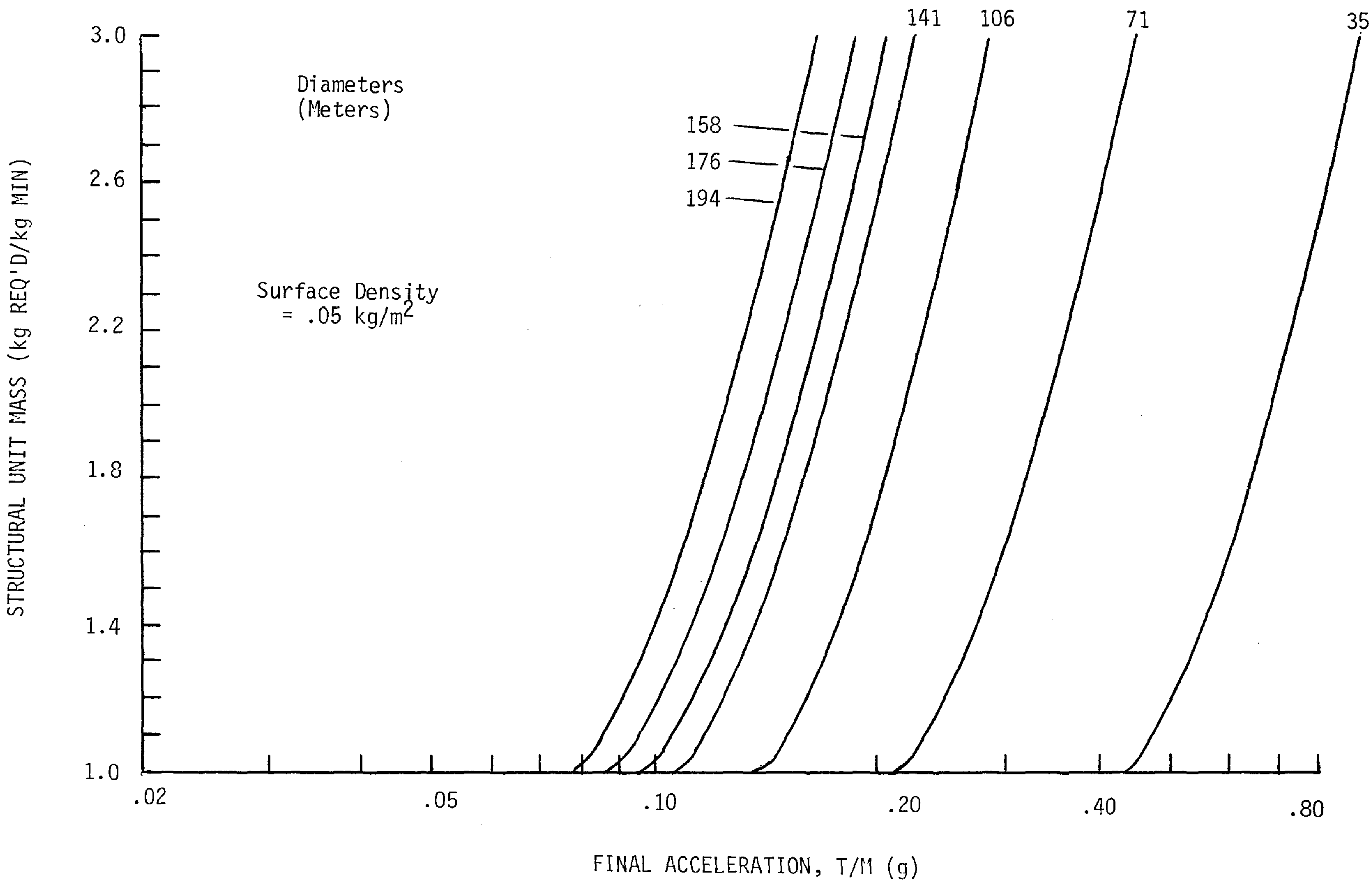


FIGURE III-14 WRAP RADIAL RIB UNIT MASS VERSUS THRUST-TO-MASS FOR SURFACE DENSITY OF 0.05 kg/m^2

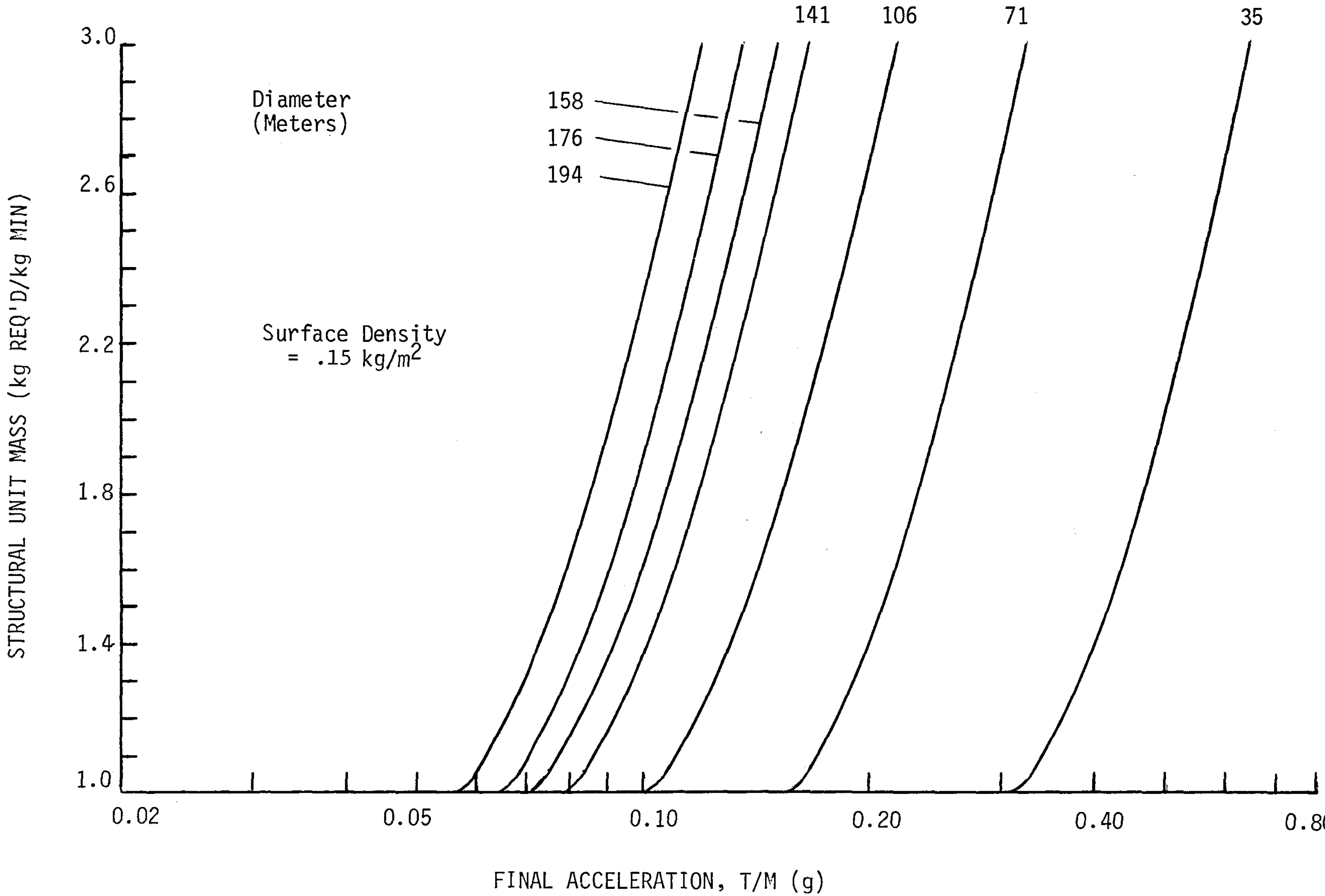


FIGURE III-15 WRAP RADIAL RIB UNIT MASS VERSUS THRUST-TO-MASS FOR SURFACE DENSITY OF 0.15 kg/m^2

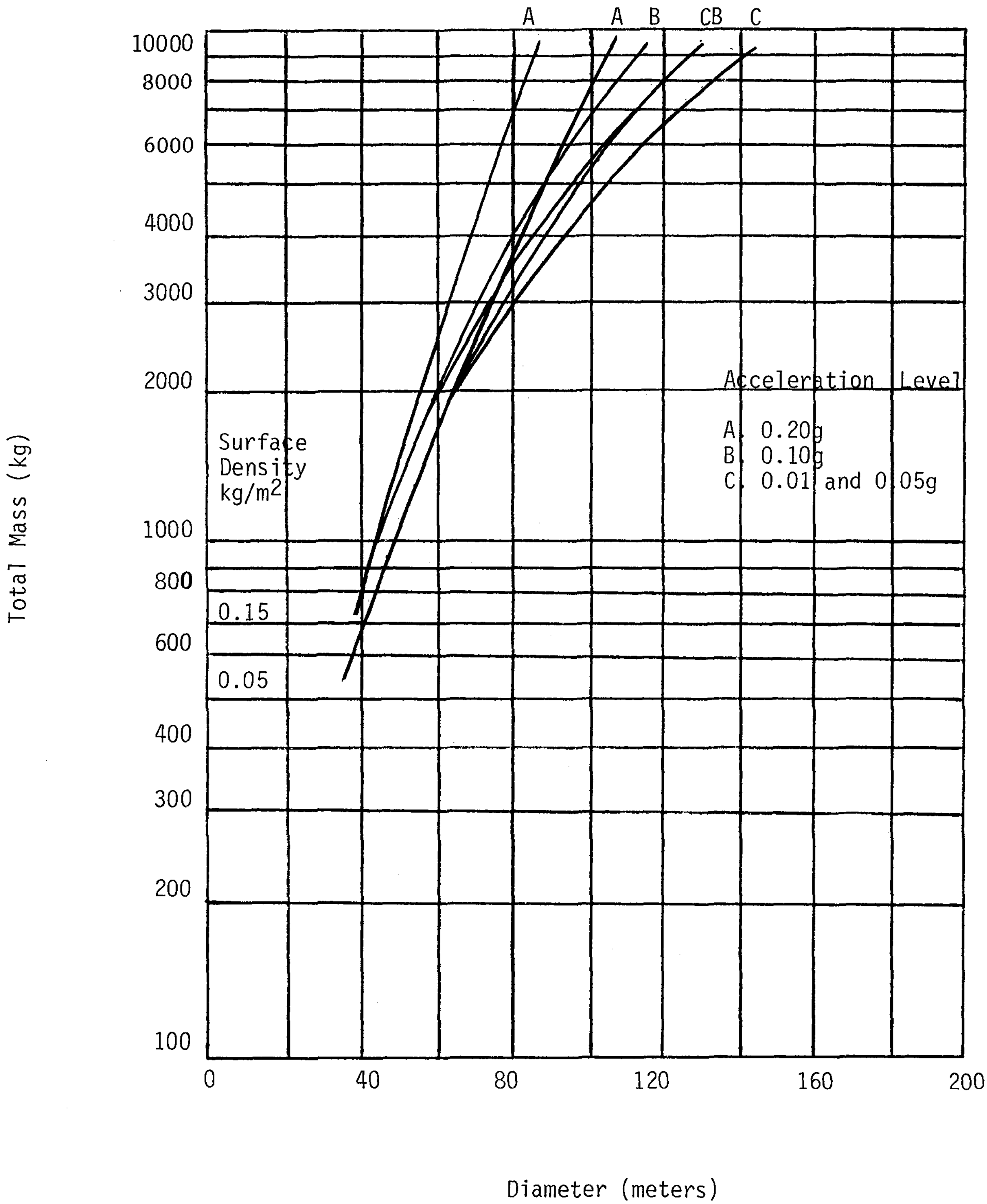


FIGURE III-16 - WRAP RADIAL RIB SYSTEM MASS VERSUS DIAMETER

TABLE III-10 - NATURAL FREQUENCIES FOR RADIAL RIB

T/M = 0.02 g				
	FREQUENCIES (Hz)			
DIAMETER	106 m		176 m	
SURFACE DENSITY	0.05 kg/m^2	0.15 kg/m^2	0.05 kg/m^2	0.15 kg/m^2
MODE				
1	0.24	0.18	0.12	0.09
2	0.97	0.73	0.51	0.40
3	2.31	1.78	1.22	0.96
4	4.22	3.32	2.23	1.77
5	6.73	5.36	3.57	2.84

TABLE III-11 - ROOT AMPLIFICATION FACTORS

DIAMETER / SURFACE DENSITY	T_R=STEP	$T_R=1/3f_1$	$T_R=2/3f_1$	$T_R=3/3f_1$	$T_R=4/3f_1$
106/0.05	1.71	1.62	1.28	1.01	1.15
106/0.15	1.75	1.63	1.29	1.01	1.16
176/0.05	1.68	1.60	1.26	1.01	1.16
176/0.15	1.70	1.61	1.27	1.01	1.16
AVERAGE	1.71	1.62	1.28	1.01	1.16

The radial rib shutdown transient analysis results are similar to the box truss shutdown transients. The amplification factor is highest at the tip due to "whip lash" effect. However, the rib root is the critical stress location due to the fact that allowable stress increases toward the tip. Therefore, root amplification is the design criterion. A representative case (176 meters diameter, 0.15 kg/m^2 mesh, T/M = 0.05) shows root amplification of 0.76 of the static stress. Therefore, shutdown transients do not impact the structural mass.

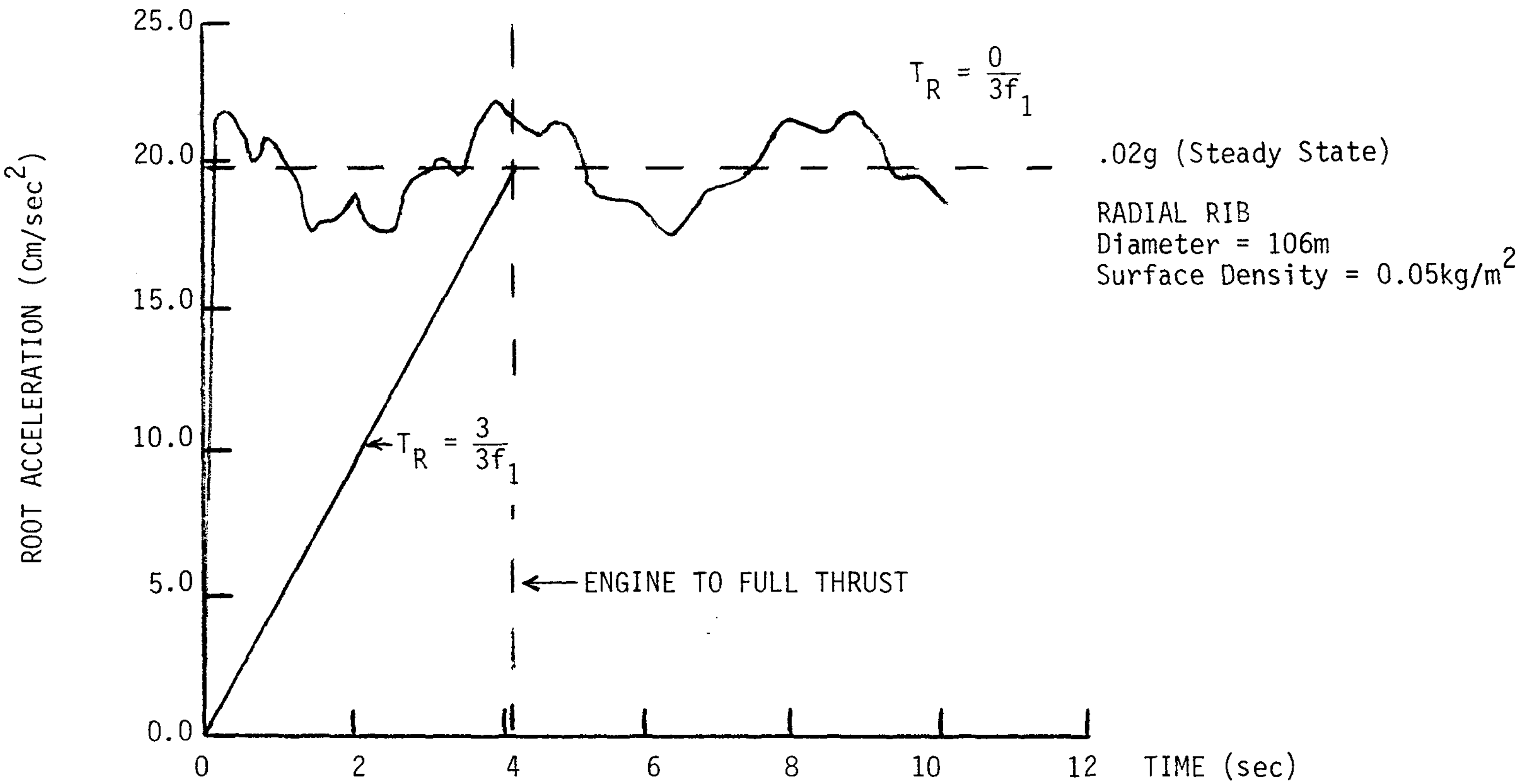


FIGURE III-17 TYPICAL ROOT ACCELERATION FOR STEP AND RAMP INPUT ($T_R = \frac{0}{3f_1}$ AND $T_R = \frac{3}{3f_1}$)

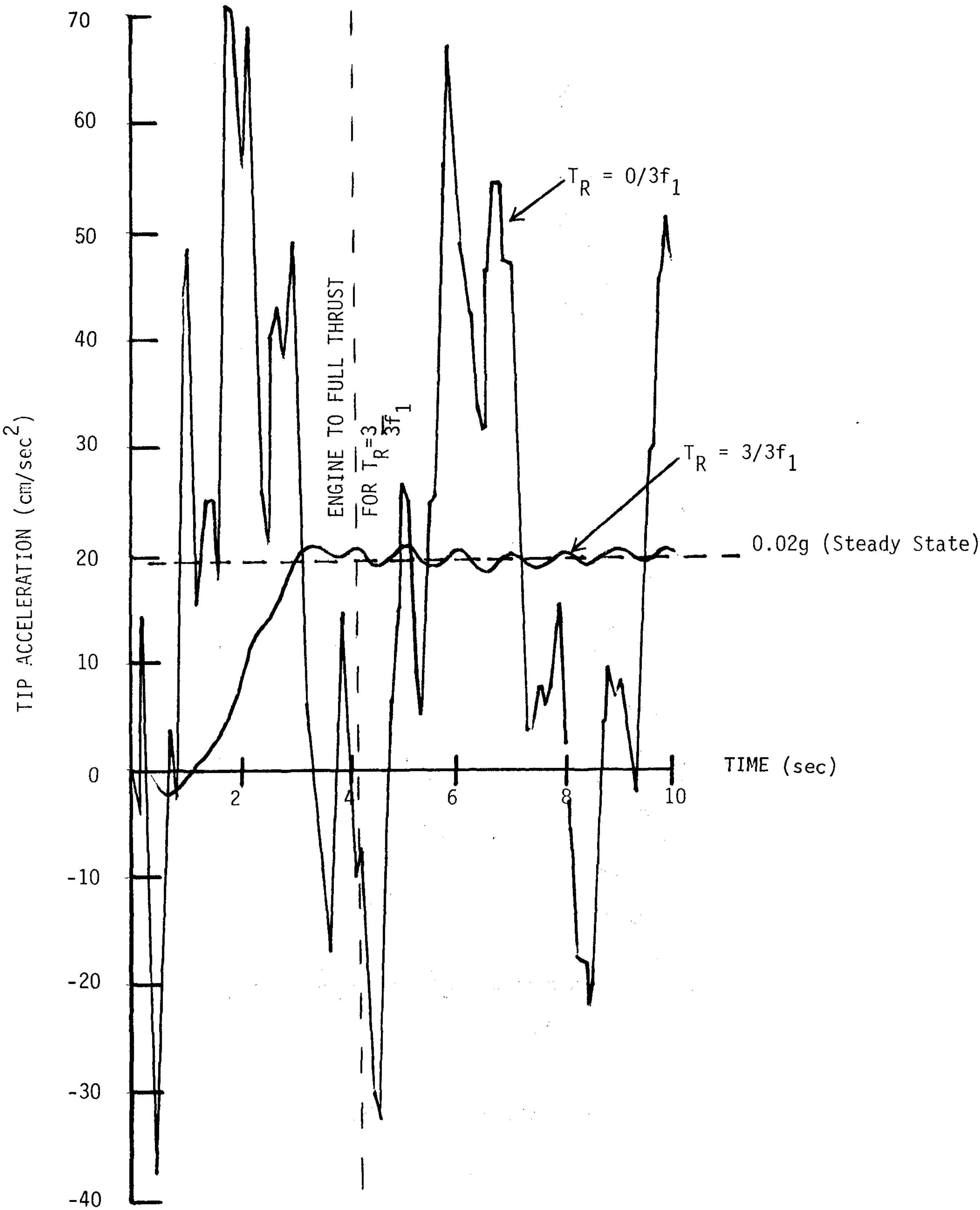


FIGURE III-18- TYPICAL TIP ACCELERATION FOR STEP AND RAMP INPUT (RADIAL RIB, 106m, SURFACE DENSITY = 0.05kg/m^2

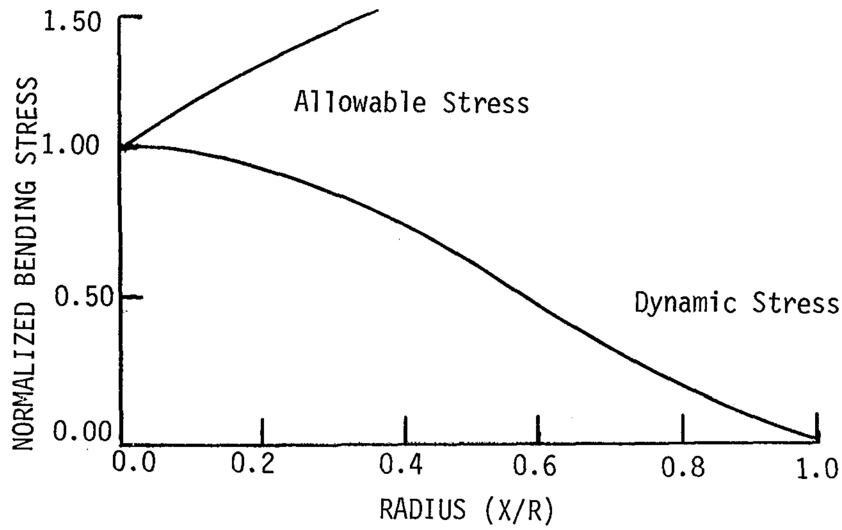


FIGURE III-19 DYNAMIC STRESS VERSUS ALLOWABLE STRESS ALONG RIB (TYPICAL)

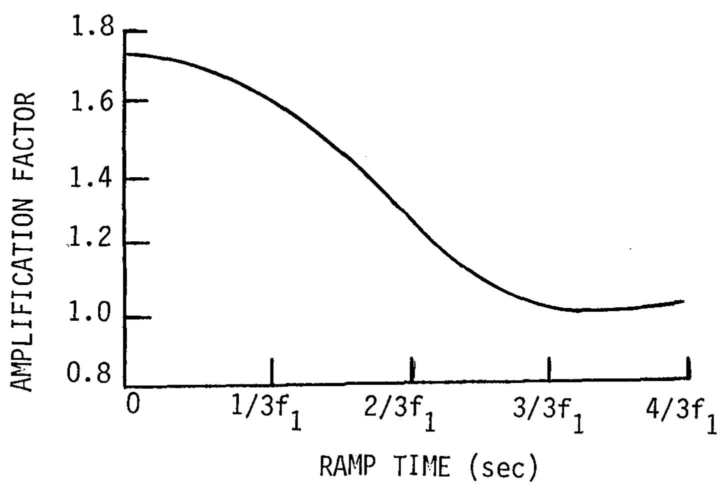


FIGURE III-20 AMPLIFICATION FACTOR FOR VARIOUS RAMP TIMES (RADIAL RIB)

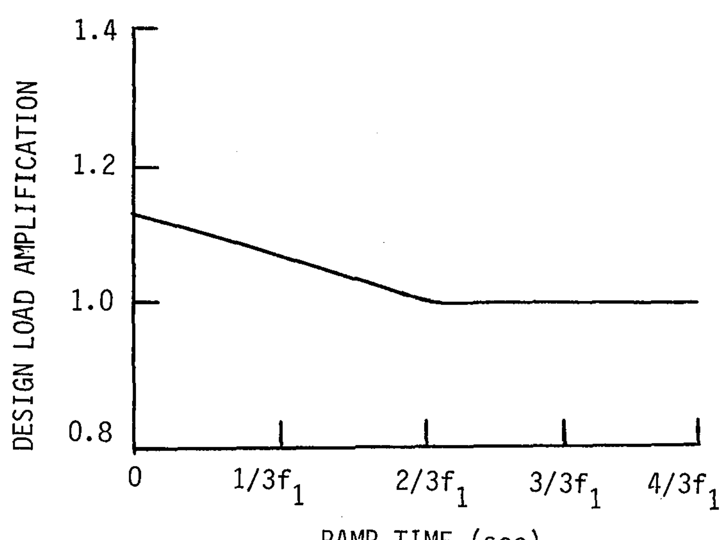


FIGURE III-21 ACTUAL DESIGN LOAD AMPLIFICATION (RADIAL RIB) (CONSTANT THRUST BURN)

TABLE III-12 RADIAL RIB TRANSIENT THRUST IMPACT - CONSTANT THRUST BURN

T_R	DESIGN AMPLIFICATION X 0.034 g's	STEADY STATE DESIGN T/M	DESIGN LOAD FACTOR	ACTUAL DESIGN LOAD AMPLIFICATIONS*	AVERAGE TRANSIENT** Kg REQ'D / Kg STEADY STATE
STEP	1.71 X 0.034 = 0.057 g's	0.05 g's	0.057 g's	1.14	1.10
$1/3f_1$	1.62 X 0.034 = 0.054 g's	0.05 g's	0.054 g's	1.08	1.05
$2/3f_1$	1.28 X 0.034 = 0.043 g's	0.05 g's	0.050 g's	1.00	1.0
$3/3f_1$	1.01 X 0.034 = 0.034 g's	0.05 g's	0.050 g's	1.00	1.0
$4/3f_1$	1.16 X 0.034 = 0.040 g's	0.05 g's	0.050 g's	1.00	1.0

*AMPLIFICATION = $\frac{\text{DESIGN LOAD FACTOR}}{\text{STEADY STATE DESIGN T/M}}$, APPLICABLE FOR ALL STEADY STATE T/M's BETWEEN 0.01 TO 0.40 g's

**AVERAGE OF ALL RADIAL RIB CASES ANALYZED

NOTE: FOR THE RADIAL RIB STUDIED, RAMP TIMES OF T_R = 0.5 TO 10 SECONDS @ T_R = $2/3f_1$ PRODUCE NO STRUCTURAL IMPACT

4. Wrap Radial Rib Summary and Conclusions

Fourteen typical radial rib configurations with diameters ranging from 35 to 194m and surface densities ranging from 0.05 to 0.15 kg/m^2 were analyzed to determine the effect of steady state thrust on structural mass. At a typical low-thrust T/M ratio of 0.05 g's there was no structural mass impact on any of the configurations which were analyzed (structural mass impact occurred at a T/M of 0.055 g's on the 194m/0.15 kg/m^2 configuration). The relatively high allowable acceleration at large diameters is due to stiffness criteria which increases the size of cantilevered ribs as diameter increases. Additionally, the radial rib concept was not sized for the higher surface densities of 0.40 and 3.42 kg/m^2. After the minimum size rib structure was affected by acceleration, each of the configurations exhibited a common trend, i.e. an exponential increase in structural mass as T/M was increased. For a given diameter and surface density the structural mass change is very sensitive to T/M and the mass increases are large over a small range of T/M.

Four typical radial rib configurations were analyzed to determine the effect of start and shutdown transients on structural mass. These analyses were conducted for a constant thrust burn strategy. Mean dynamic amplification factors for start transients varied from 1.71 for a step thrust input to 1.01 for a thrust ramp equal in time to the period of the fundamental frequency of the combined LSS-OTV system. For a constant thrust burn strategy, the most critical start condition from a dynamic standpoint is the apogee burn. Analysis at this condition indicated an average structural mass impact (relative to steady state) of 10% for a step thrust input and negligible mass impact for ramps equal in time to 2/3 of the fundamental period. For all configurations considered, start times which produced negligible impact ranged from 0.5 to 10 seconds. Shutdown transient analyses indicated that an instantaneous thrust cutoff at the end of the apogee burn produced root amplification factors of less than 1.0 and did not impact structural mass.

C. Hoop and Column Analysis

1. Assumptions and Approach

The data generator program for a hoop and column configuration (see Figures II-5 and II-6) spacecraft uses a repetitive arrangement. This algorithm provides for automatic data generation for this type of structure in a format suitable for NASTRAN analysis.

Some of the other features of the program are that: 1) it allows for either a convex or concave taper in the central supporting column by simply specifying the diameters at center and the end; 2) it provides pretensioning in the structure that may be necessary which is provided for and simulated by means of a pseudo-temperature field - the degree and extent of which is selected through appropriate input data; 3) any number of radial stays or hoop sections, which are modelled as beams, may be present; and; 4) it provides comprehensive analysis within a reasonable approximation, including the effect of masses concentrated at specific points.

The criteria for the static analysis and methodology used are as follows. It was specified that under inertial loading there are no net compressive stresses (slack) in any of three groups of stay numbers. To provide for this, a pretension load was introduced in the stays to counter the compressive stresses generated by the orbit transfer effect. A minimum residual tension load of approximately 20 N is required in any of the stays.

The other design criterion has the structural member mass being based on a 20% margin with strength analysis of the members incorporating minimum material properties for both stay and rim (E = 11.0 X 10^6 N/cm^2/ ρ = 2000 kg/m^3) and a factor of safety of 1.5. The stay tape allowable limit was 31,700 N/cm^2. Allowable failure modes of the structure considered Euler column and material failure. Nominal sizes for stay and rim are 0.95 cm X 0.013 cm and 10.8 cm diameter X 0.038 cm thick, respectively. The hub, sized by orbiter launch loads, remains constant.

Once the appropriate conditions have been simulated and the necessary data generation completed, the resulting finite element model is analyzed using NASTRAN to obtain the total mass properties and load/stress and displacement data at requisite points of the structure.

2. Hoop and Column Steady State Analysis

Static models of the hoop and column design were used to generate the parametric data necessary to assess the affects of the steady-state thrust-to-mass ratios on structural sizing and resulting system mass. These models were used to generate the loads in each member and then each member was subsequently sized to carry the load. The analysis was then iterated based upon the new member mass and resulting new loads.

Results from 32 cases of 50, 100 and 200 meter diameters over a range of surface densities and T/M ratios are presented in Tables III-13, III-14, and III-15. The key parameter determined by the analysis is the structural mass impact (kg required/kg minimum) of the various diameter, surface density, and T/M combinations. Figure III-22 presents, in graphical form, a summary of the results of the steady-state analysis. The results show that in the T/M range of 0.05 - 0.10 g's, the structural mass impact is small (from 0% to 40%) except for the higher surface densities at a diameter of 200 meters.

System mass versus diameter for the three surface masses with thrust-to-mass as a parameter are presented in Figure III-23.

3. Hoop and Column Transient Thrust Effect

Once the member sizings had been determined based on steady-state thrust loads a finite element model was generated to perform the transient dynamic effects analysis. The transient analysis effects for the step thrust application were determined for the 50, 100 and 200 meter cases as the static analyses. Table III-16 presents the fundamental structural frequencies of the free-free hoop column system with a 7940 Kg stage mass. For this structural system the primary structural frequency is the hoop and mesh mass vibrating in a pogo mode with the stay straps operating as a spring. Because of the single degree of freedom type mode, the amplification factor follows very close to the ideal single degree of freedom system. Table III-17

TABLE III-13 - 50 METER DIAMETER HOOP AND COLUMN STEADY STATE RESULTS

SURFACE DENSITY (kg/m2)	T/M g's	STAY FORCE (NEWTONS)	STAY DELTA MASS (kg)	HOOP COMPRESSION (NEWTONS)	HOOP DELTA MASS (kg)	TOTAL DELTA MASS (kg)	kg REQUIRED / kg MINIMUM
	0.02	30	0	310	0	0	1.0
0.05	0.05	44	0	420	0	0	1.0
	0.20	118	0	990	0	0	1.0
	0.80	412	0	3270	1	1	1.0
	0.02	40	0	400	0	0	1.0
0.15	0.05	72	0	680	0	0	1.0
	0.20	224	0	1990	0	0	1.0
	0.80	838	3	7350	33	36	1.11
	0.02	68	0	660	0	0	0
0.40	0.05	140	0	1310	0	0	0
	0.20	500	1	4570	13	14	1.04
	0.80	1940	12	17570	86	98	1.30

NOTES: MINIMUM STRUCTURE = 322 kg
MAXIMUM RIM DIAMETER = 52 cm (ORBITER PACKAGING CONSTRAINT)

TABLE III-14 - 100 METER DIAMETER HOOP AND COLUMN STEADY STATE RESULTS

SURFACE DENSITY (kg/m2)	T/M g's	STAY FORCE (NEWTONS)	STAY DELTA MASS (kg)	HOOP COMPRESSION (NEWTONS)	HOOP DELTA MASS (kg)	TOTAL DELTA MASS (kg)	kg REQUIRED / kg MINIMUM
	0.02	50	0	550	0	0	1.0
0.05	0.05	94	0	960	0	0	1.0
	0.20	314	0	3010	43	43	1.08
	0.80	1780	28	14970	214	242	1.44
	0.02	92	0	1000	0	0	1.0
0.15	0.05	202	0	2100	21	21	1.04
	0.20	750	7	7590	125	132	1.24
	0.80	3960	72	35742	381	453	1.82
	0.02	198	0	2130	21	21	1.04
0.40	0.05	464	2	4860	81	83	1.15
	0.20	1796	28	18610	249	277	1.50
	0.80	9610	185	89600	655	840	2.52

NOTES: MINIMUM STRUCTURE = 554 kg
MAXIMUM RIM DIAMETER = 38 cm (ORBITER PACKAGING CONSTRAINT)

TABLE III-15 - 200 METER DIAMETER HOOP AND COLUMN STEADY STATE RESULTS

SURFACE DENSITY (kg/m^2)	T/M g's	STAY FORCE (NEWTONS)	STAY DELTA MASS (kg)	HOOP COMPRESSION (NEWTONS)	HOOP DELTA MASS (kg)	TOTAL DETLA MASS (kg)	kg REQUIRED / kg MINIMUM
	0.02	126	0	2610	68	68	1.06
0.05	0.05	284	0	5560	186	186	1.17
	0.20	1710	104	29830	1093	1197	2.12
	0.02	294	0	5700	191	191	1.18
0.15	0.05	704	25	13330	392	417	1.39
	0.20	4944	360	85910	3506	3866	4.62
	0.02	722	26	13850	403	429	1.40
0.40	0.05	1776	110	33725	1261	1371	2.29

NOTES: MINIMUM STRUCTURE = 1066 kg
MAXIMUM RIM DIAMETER = 19 cm (ORBITER PACKAGING)

TABLE III-16 Natural Frequencies for Hoop/Column

T/M = 0.02 g's

DIAMETER (METERS)	SURFACE DENSITY (Kg/M^2)	FUNDAMENTAL FREQUENCY (HZ)
	0.05	1.83
50	0.15	1.15
	0.40	0.69
	0.05	0.58
100	0.15	0.35
	0.40	0.22
	0.05	0.15
200	0.15	0.09
	0.40	0.06

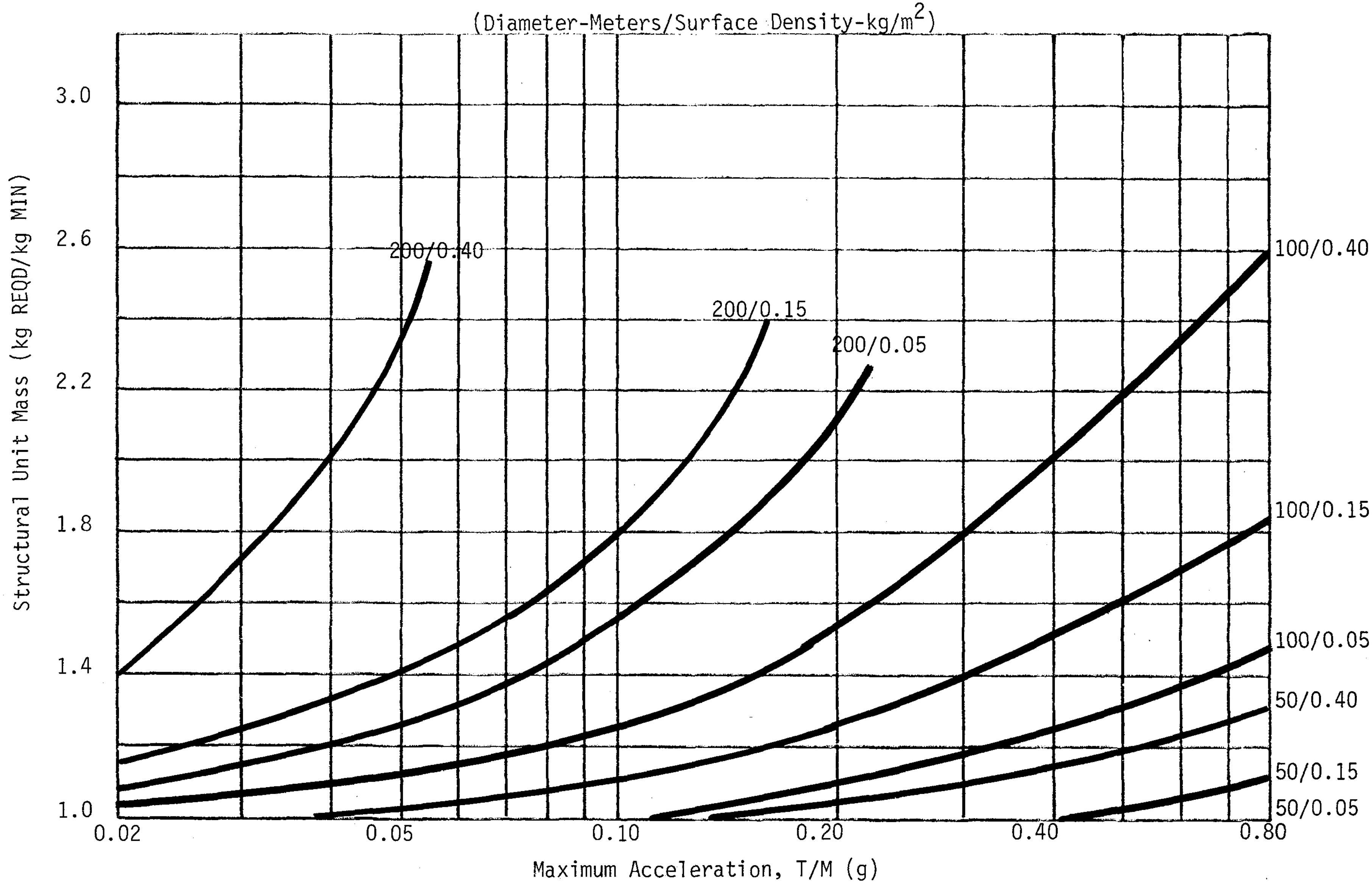


FIGURE III-22- UNIT MASS VERSUS FINAL THRUST TO MASS (HOOP AND COLUMN)

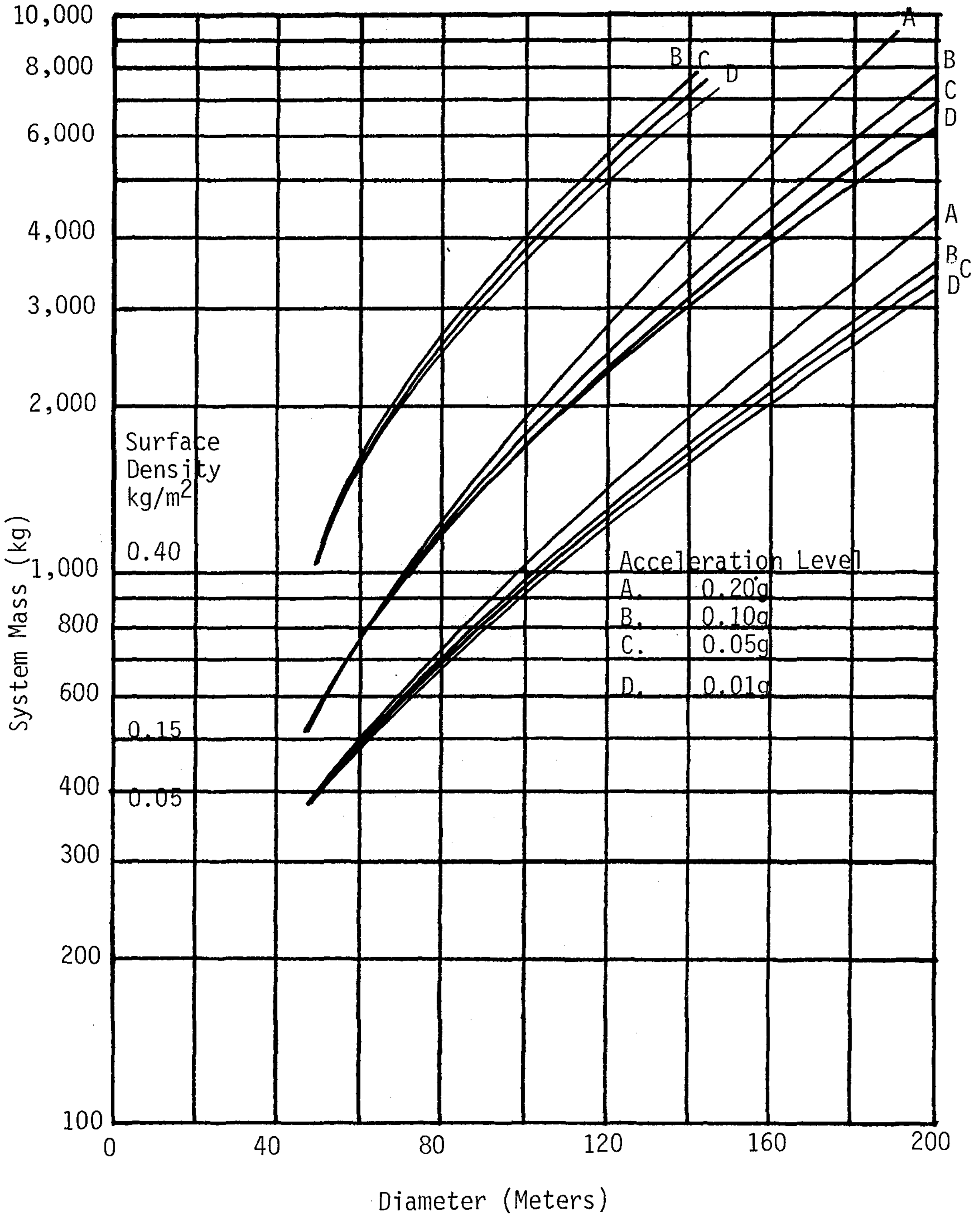


FIGURE III-23- HOOP AND COLUMN SYSTEM MASS VERSUS DIAMETER

TABLE III-17 Typical Dynamic Amplification Factors for the Hoop Pogo Mode

THRUST INPUT	AMPLIFICATION FACTOR
TR = Step	2.0
TR = 1/3f,	1.86
TR = 2/3f,	1.38
TR = 3/3f,	1.01
TR = 4/3f,	1.16

presents typical amplification factors for the hoop and column system. Table III-18 presents the determination of the actual design load amplification factor as applied to the actual steady state acceleration at start of apogee burn. Table III-18 also presents the average structural mass impact for the transient thrust application. The results are similar to the box truss and radial rib with no structural impact at $T_R = 2/3f_1$, and slightly less than 10% impact for a step thrust input.

4. Hoop and Column Summary and Conclusions

Nine typical hoop and column configurations with diameters ranging from 50 to 200 m and surface densities ranging from 0.05 to 0.40 kg/m^2 were analyzed to determine the effect of steady state thrust on structural mass. At a typical low-thrust T/M ratio of 0.05 g's the structural mass impact was relatively small (12% or less) for six of the nine cases. Exceptions were the maximum diameter (200 m) cases with surface densities of 0.05, 0.15, and 0.40 kg/m^2 where the structural mass impacts at 0.05 g's were 23%, 40%, and 134% respectively. Each of the configurations exhibited a common trend after the minimum gage structural mass was affected by acceleration, i.e. an exponential increase in structural mass as T/M was increased. For a given diameter and surface density, the mass change is relatively small over a wide range of T/M and, with the exception of the maximum diameter cases noted above, only small reductions in structural mass are realized at T/M ratios below 0.05 g's.

TABLE III-18 Hoop/Column Design Transient Thrust Impact - Constant Thrust Burn

T_R	Design Amplification x 0.034 g's	Steady State Design T/M	Design Load Factor	Actual Design Load Amplification*	Average Transient** Kg Req'd/Kg Steady State
Step	2.0 x 0.034 = 0.068 g's	0.05 g's	0.068 g's	1.36	1.07
1/3f,	1.86 x 0.034 = 0.063 g's	0.05 g's	0.063 g's	1.26	1.01
2/3f,	1.38 x 0.034 = 0.047 g's	0.05 g's	0.050 g's	1.00	1.00
3/3f,	1.01 x 0.034 = 0.034 g's	0.05 g's	0.050 g's	1.00	1.00
4/3f,	1.16 x 0.034 = 0.039 g's	0.05 g's	0.050 g's	1.00	1.00

$$*\text{Amplification} = \frac{\text{Design Load Factor}}{\text{Steady State Design T/M}}$$, Applicable for all steady state T/M's between 0.01 to 0.40 g's

**Average for all hoop and column cases analyzed.

NOTE: For the Hoop/Columns studied, ramp times of T_R = 0.3 to 11.0 seconds @ T_R = 2/3f, produce no structural impact.

Three typical hoop and column configurations were analyzed to determine the effect of start and shutdown transients on structural mass. Mean dynamic amplificaiton factors for start transients varied from 2.0 for a step input to 1.01 for a thrust ramp equal to the time of the fundamental frequency of the combined LSS-OTV system. For a constant thrust burn strategy at the critical apogee burn, the analysis indicated a 7% structural mass impact for a step thrust input and no impact at a ramp time equal to 2/3 of the structural fundamental period. For all configurations considered start times which produced no structural mass impact ranged from 0.3 to 11 seconds. Shutdown transients produced amplification factors of approximately 1.0 and did not impact the structural mass.

D. Multi-Point Concept Assessment

1. Multi-Point Thrust Approach

The three structural concepts were evaluated to determine their applicability to multi-point thrust application. The box truss, with its large number of hard points for attachment, provides complete flexibility for location of the propulsion system. The hoop and column concept requires that propulsion system locations be limited to the column and the hoop. Although this limits variability of locations, the concept is definitely applicable for multi-point thrust application. The radial rib antenna has only one hard point - the hub. Therefore, multi-point thrust is not applicable to the radial rib concept. The hoop and column and box truss were selected for further study.

2. Box Truss Multi-Point Analysis

Analyses performed in previous sections only addressed loads in the truss caused by thrust from a single engine attached to the geometric center of the LSS. Subsequent analyses entertained the possibility of distributing the same thrust over a larger portion of the truss by virtue of several strategically positioned smaller thrusters.

The idea of reducing the structural mass of the box truss by means of multiple thrust application points is intuitively appealing. A more uniformly distributed thrust results in more uniform acceleration, hence more uniform distributions of internal loads, smaller deformations, and less structural mass are required for a given g-level. Ideally, one might envision a thruster being attached to the base of each vertical member which, when fired with the proper amount of thrust and in phase with all the other thrusters, would result in the perfect uniform acceleration of the truss. Under such conditions each surface member carries only the bending load arising from the acceleration of its own mass and each vertical member carries only the axial load of its mass plus a fraction of the mass with associated surface members and surface mesh.

If a box truss with one thruster per vertical member is considered one extreme of the spectrum, then clearly one centralized thruster is the other. To strike a balance between these extremes and assess sensitivity of structural mass to the number of thrust application points, two multi-point thrust configurations were chosen. A quarter-segment model is illustrated in

Figure III-24 for five-point and nine-point schemes. For each box truss, the stations (verticals) at which the thrusters were located were chosen in an attempt to minimize the effective bending (i.e., compression of bottom surface member, extensions of top) of the truss. Furthermore, for the purposes of analysis it was assumed that the magnitude of the force applied by each thruster would be, by design, that required to keep all thruster stations in a plane perpendicular to the direction of net thrust/acceleration, thereby minimizing gross deformations of the truss.

The multi-point structural analyses were performed on 71, 141 and 194 meter designs. It was felt that these structures were the most representative.

The following approach was taken in the multi-point steady-state analysis for the condition of uniform acceleration achieved during the orbit transfer burn after start-up transients subside.

1. For a given diameter and a given surface density, a finite element model of the truss was developed using the structural properties of the lightest of each of the admissable truss elements (e.g. surface members, vertical members and diagonals).

2. This "minimum gage" configuration was subjected to a baseline steady state g-level of .05 g and internal loads calculated.

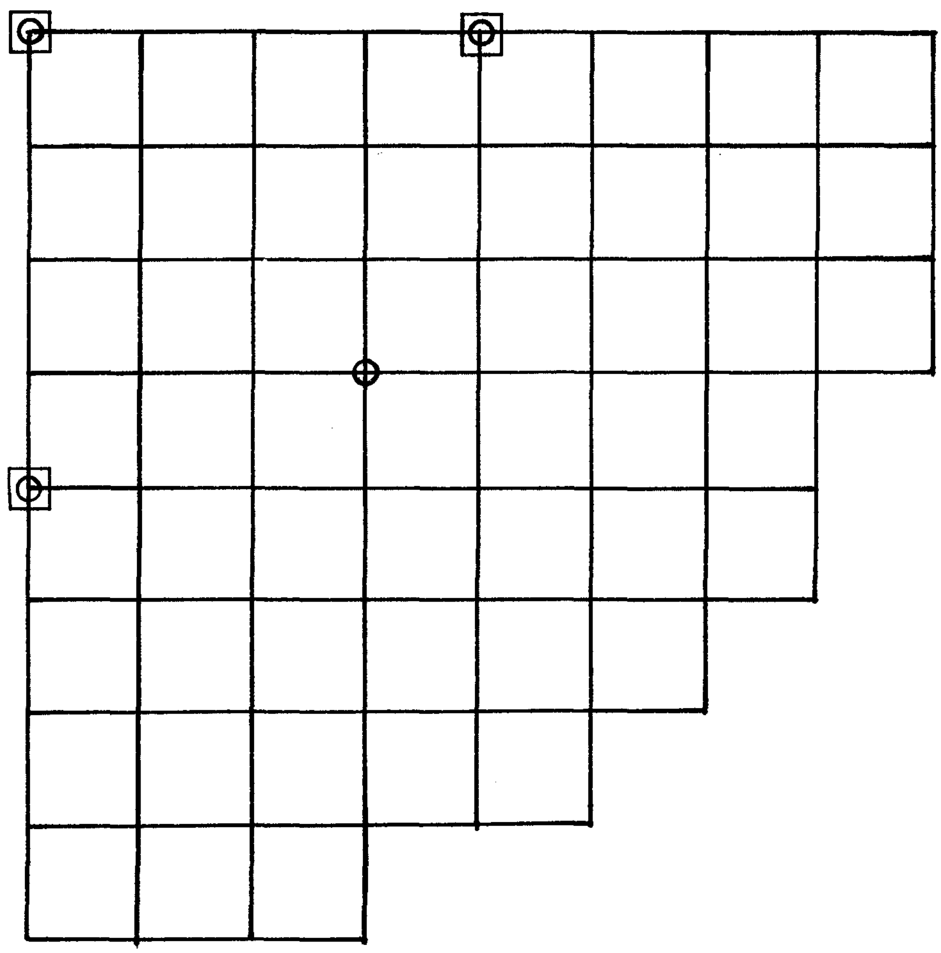
3. Based on these loads, the members of the truss were resized as required for .05, .20 and .40 g loads and the resulting structural mass estimated.

The process is shown in the form of a flow chart in Figure III-25. Note that internal loads for the .20 and .40 g cases were derived by scaling the loads from the .05 g case by a factor of 4 and 8, respectively. Based on these loads the truss members were resized, but the candidate truss was not reanalyzed to ascertain whether the increase in mass and, hence, body force loads was greater than the corresponding increase in strength. The omission of subsequent interactions on the resized truss was justifiable because:

1) Based on experience gained in the single-point analyses, resizing a box truss based strictly on scaled loads generally results in a conservative design (i.e., strength generally increases faster than body force loads); and

2) The effort and expense associated with refining the mass estimates could not be justified in light of the wide range and general nature of the designs under consideration (i.e., subsequent iterations were warranted only for a specific spacecraft and a specific mission).

Figures III-26, III-27, and III-28 present the box truss, steady state multi-point thrust application structural mass impact. The results are summarized below:

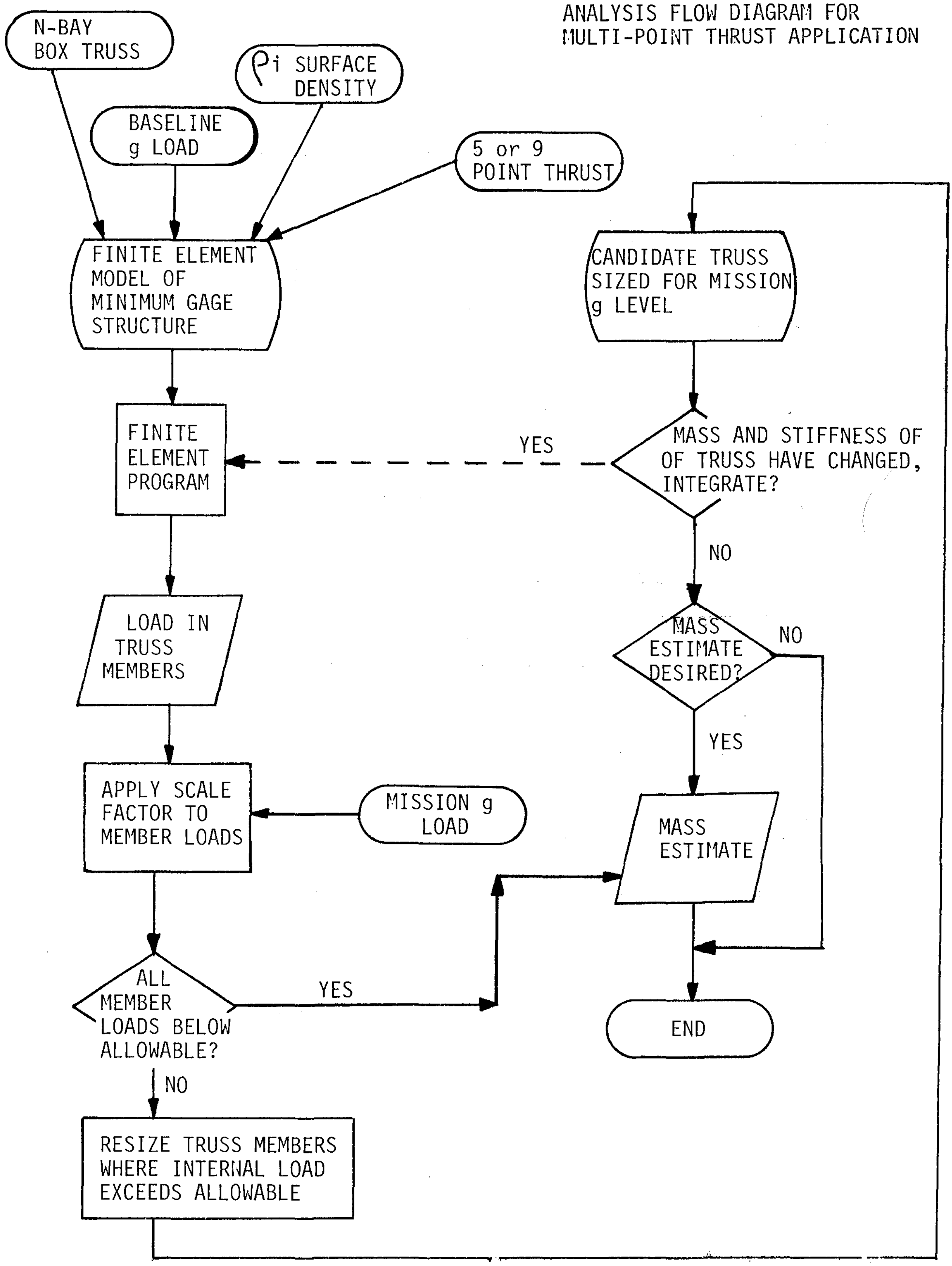


MULTI-POINT (5 POINT) THURST LOCATIONS

MULTI-POINT (9 POINT) THRUST LOCATIONS

FIGURE III-24-BOX TRUSS MULTI-POINT THRUST LOCATIONS

FIGURE III-25
ANALYSIS FLOW DIAGRAM FOR
MULTI-POINT THRUST APPLICATION



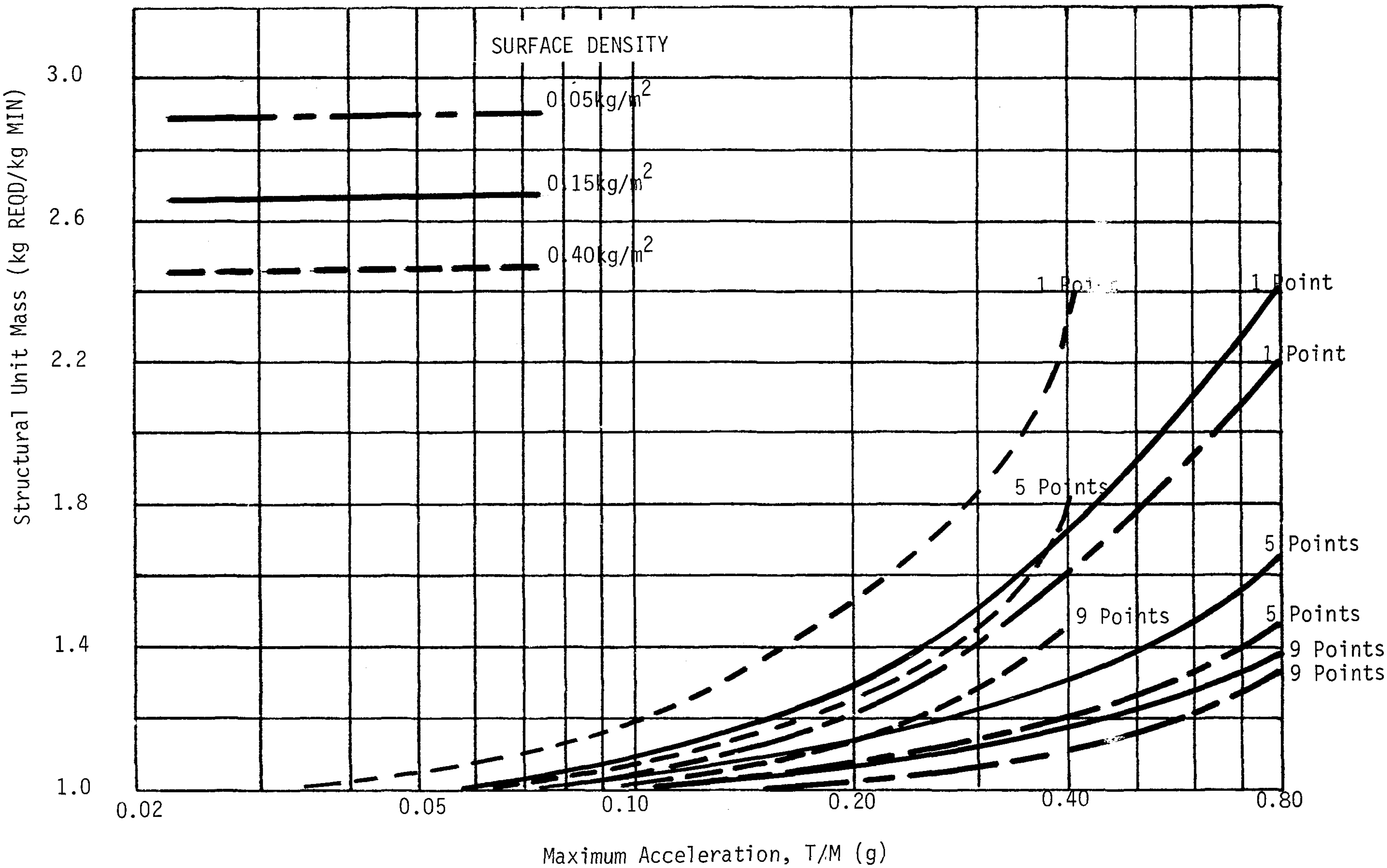


FIGURE III-26- 1, 5, AND 9 POINT THRUST IMPACT FOR 71 METER (BOX TRUSS)

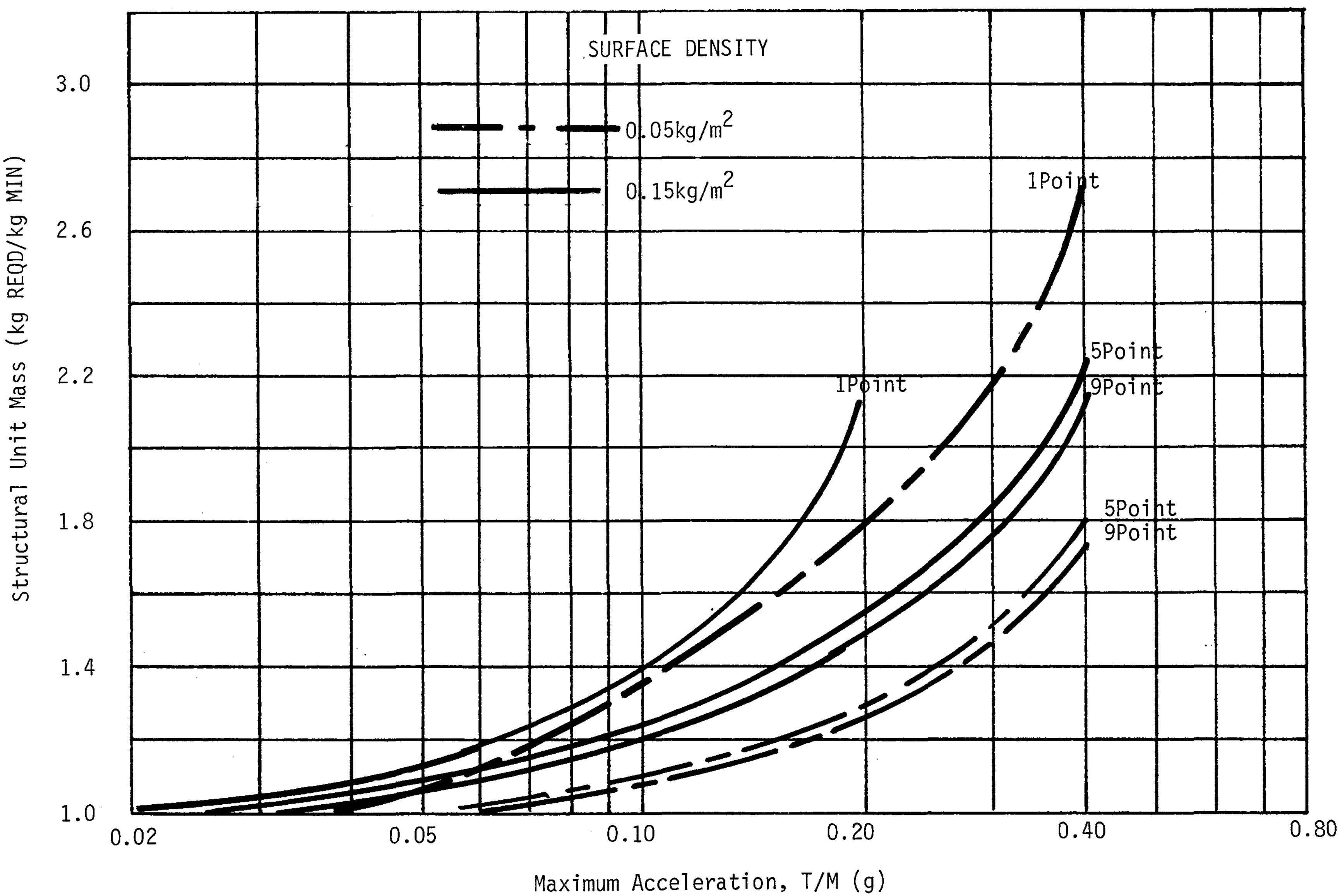


FIGURE III-27- 1, 5, AND 9 POINT THRUST IMPACT FOR 141 METER (BOX TRUSS)

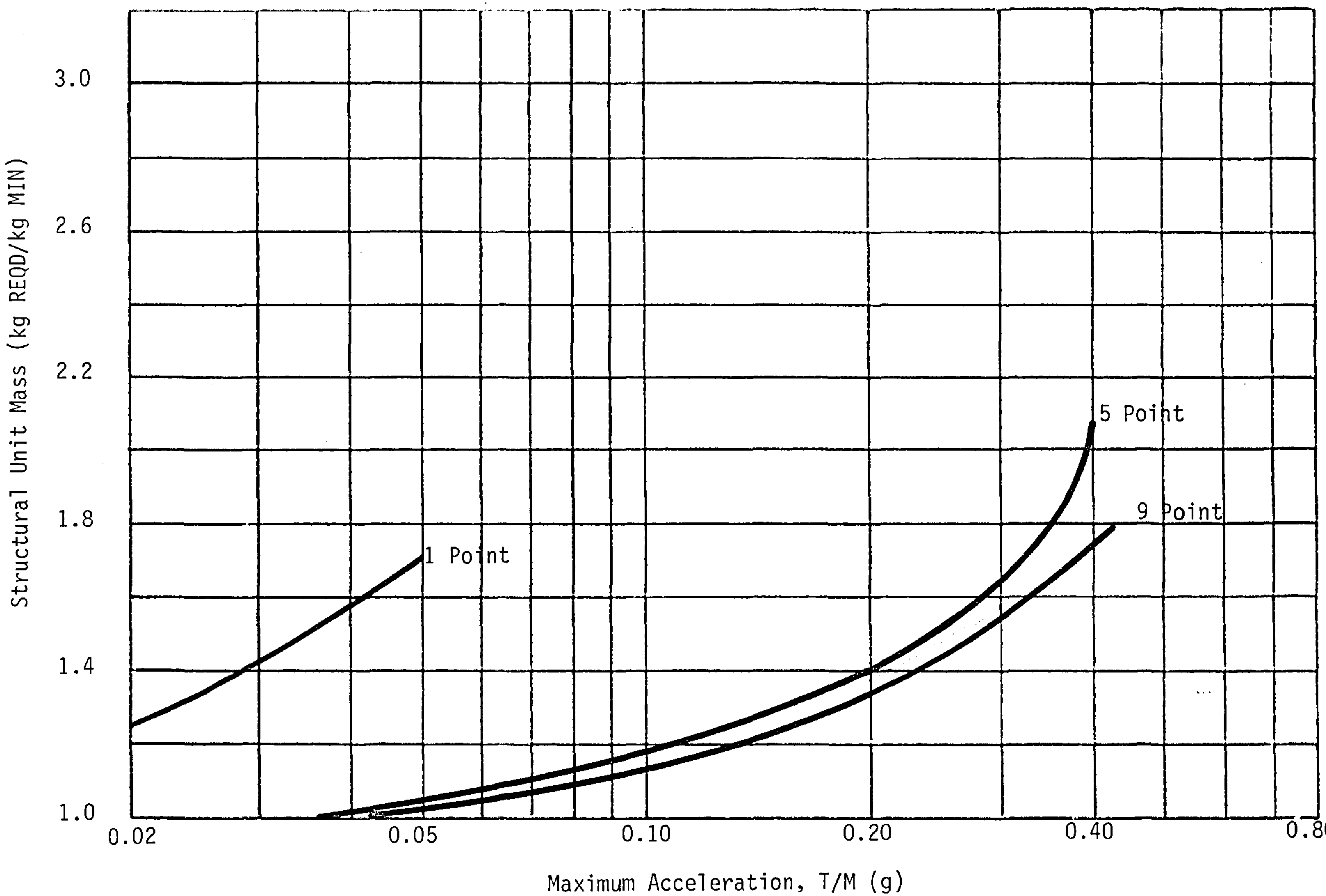


FIGURE III-28- 1, 5, AND 9 POINT THRUST IMPACT FOR 194 METER AND 0.05kg/m^2 (BOX TRUSS)

1. By utilizing a 5 point thrust application, a factor of $\backsimeq$ 2 increase in thrust can be allowed without a change in structural mass impact.

2. By going from a 5 point to a 9 point thrust application, less than a 50% increase in thrust can be realized for no change in structural mass impact

The results indicate that for these size ranges, multi-point thrust does not provide enough of a performance enhancement to warrant the added stage complexity. This is principally based on the small changes in payload mass as f(T/M) over the range of accelerations considered herein (See Sections IV & V).

Although analysis was not performed to determine the effect of engine phasing errors, there will be a negative impact reducing the allowable thrust levels that were determined. In addition, the required phasing of thrusters may be too complex to implement within current projected capabilities of the guidance and propulsion subsystems.

The biggest obstacle in the path of an analytical approach to the structural response of the box truss during dynamic events such as engine startup and shutdown is the non-linear response of the structure. This phenomenon made finite element analysis of the multi-point thrust schemes relatively more complex than analysis of single-point. Consequently conclusions regarding multi-point shutdown were based on the following reasoning rather than explicit results.

Since the deflections and loads obtained in the multi-point analysis for a given steady-state g-load were considerably less than those obtained in the single-point it follows that the structural response of the multi-point box truss would be less than the single-point thrust, given ideal phasing in engine firing. Dynamic amplification factors from the single-point analyses maximizing at 2.05 for a step thrust input, resulted in a 1.4 design load amplification factor. Given that most of the response of the truss was in the first mode, and for multi-point thrust the tendency to excite the first mode will be substantially less, it would appear conservative to assume an average dynamic amplification of 2.0 for the worst case of multi-point dynamics. This results in a 1.36 design load amplification factor. Since the increase in required structural mass for a given increase in steady-state g-load is considerably less for the multi-point case than the single point, it follows that if the average dynamic amplification of 2.0 is used to obtain an "equivalent" steady state g-level, the corresponding increase in required mass will be even less significant in the multi-point case than the single-point case. Table III-19 presents the results of the 1, 5 and 9 point thrust application for the box truss. As can be seen, the thrust transient impacts are slightly lower for the multi-points. The 10% average structural mass impact for the single-point is reduced to 5% for the 5 point.

3. Hoop and Column Multi-Point Analysis

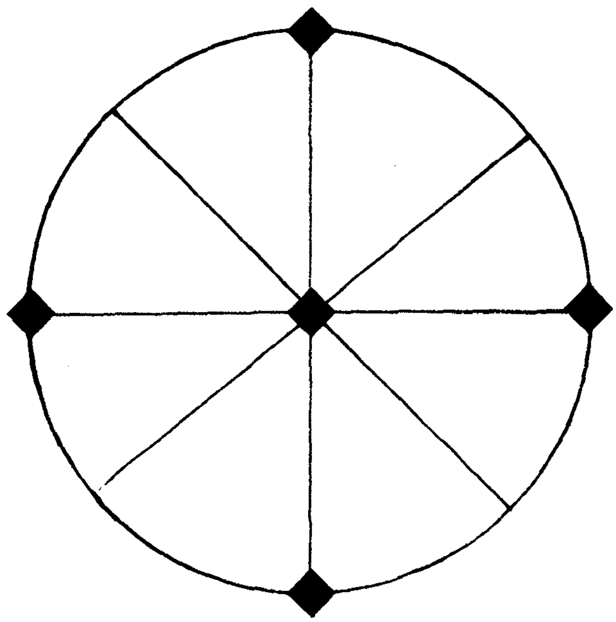
The hoop and column design allows for placement of one thruster on the column and the remaining 4 or 8 thrusters equally spaced on the hoop (Figure III-29). By thrusting on the hoop a reduction in the hoop compression load is achieved. However, there is no decrease in the loads produced by the

TABLE III-19 - BOX TRUSS STRUCTURAL MASS IMPACT FOR STEP INPUT

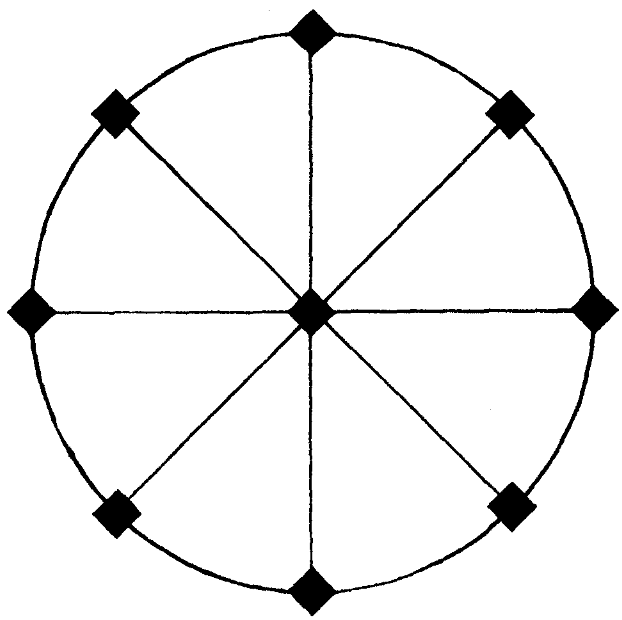
DIAMETER METERS	T/M g's	SURFACE DENSITY (kg/m^2) 0.05	0.15	0.40
194	.02	1.03/1.02/1.00(1)(2)		
	.05	---/1.10/1.08		
141	.02	1.21/1.00/1.00	1.02/1.00/1.00	
	.05	1.03/1.00/1.00	1.11/1.08/1.07	
	.20	1.18/1.14/1.10	1.22/1.16/1.12	
71	.02	1.00/1.00/1.00	1.01/1.00/1.00	1.03/1.00/1.00
	.05	1.01/1.00/1.00	1.03/1.00/1.00	1.12/1.08/1.06
	.20	1.00/1.00/1.00	1.11/1.07/1.06	1.38/1.25/1.21

(1) kg REQUIRED/kg STEADY STATE
(2) SINGLE POINT/5 POINT/9 POINT

FIGURE III-29-HOOP AND COLUMN MULTI-POINT THRUST POINTS OF APPLICATION



5-Point Application



9-Point Application

suspended surface. Therefore, the overall reduction in loads are not as dramatic. Figures III-30, III-31, and III-32 present the hoop and column, steady-state multi-point thrust application, structural mass impact. The results show that by utilizing a 5 point thrust application, less than a factor of two increase in thrust can be allowed without a change in structural mass impact. The 9 point thrust application shows only a small improvement over the 5 point.

Like the box truss, the results indicate that for these size ranges, multi-point thrust does not provide enough of a performance enhancement to warrant the added stage complexity.

The hoop and column transient analysis assumed a dynamic amplification factor of 2.0 resulting in a design load factor of 1.36. The results are summarized in Table III-20. Again, the results show a small decrease in the structural mass impact.

TABLE III-20 - HOOP AND COLUMN STRUCTURAL MASS IMPACT FOR STEP INPUT

DIAMETER METERS	T/M g's	SURFACE DENSITY (kg/m^2) 0.05	0.15	0.40
50	0.02	1.00/1.00/1.00(1)(2)	1.00/1.00/1.00	1.00/1.00/1.00
	0.05	1.00/1.00/1.00	1.00/1.00/1.00	1.00/1.00/1.00
	0.20	1.00/1.00/1.00	1.00/1.00/1.00	1.00/1.00/1.00
	0.80	1.03/1.00/1.00	1.05/1.00/1.00	1.06/1.02/1.00
100	0.02	1.00/1.00/1.00	1.00/1.00/1.00	1.02/1.00/1.00
	0.05	1.00/1.00/1.00	1.02/1.00/1.00	1.06/1.02/1.00
	0.20	1.04/1.00/1.00	1.05/1.01/1.00	1.07/1.03/1.01
	0.80	1.07/1.03/1.01	1.10/1.06/1.04	1.13/1.09/1.07
200	0.02	1.02/1.00/1 00	1.04/1.00/1.00	1.17/1.13/1.11
	0.05	1.04/1.00/1.00	1.16/1.12/1.10	1.53/1.40/1.32
	0.20	1.20/1.15/1.13	1.28/1.20/1.15	

(1) kg REQUIRED/kg STEADY STATE
(2) SINGLE POINT/5 POINT/9 POINT

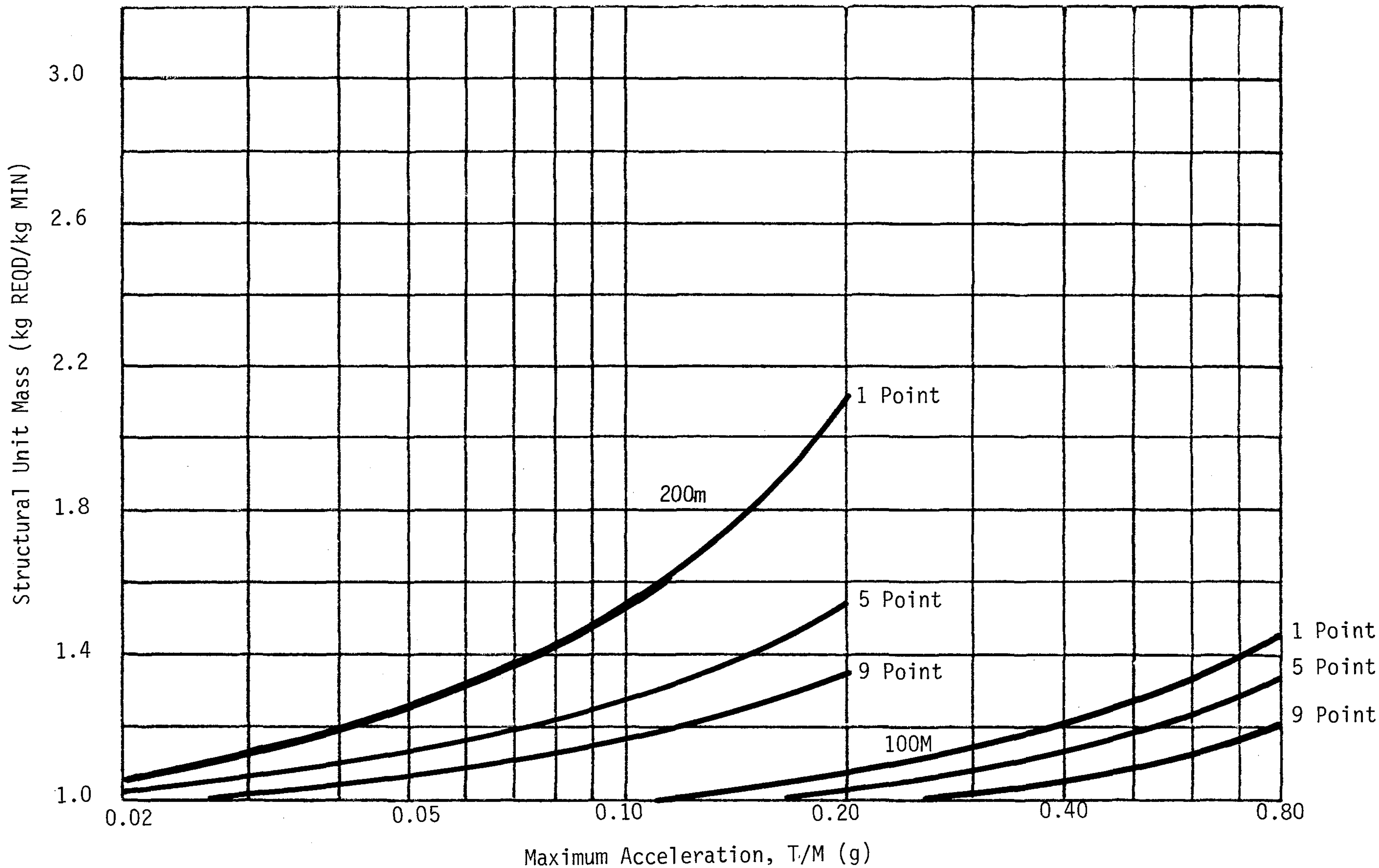


FIGURE III-30- 1, 5, AND 9 POINT THRUST IMPACT FOR 0.05kg/m^2 SURFACE DENSITY (HOOP AND COLUMN)

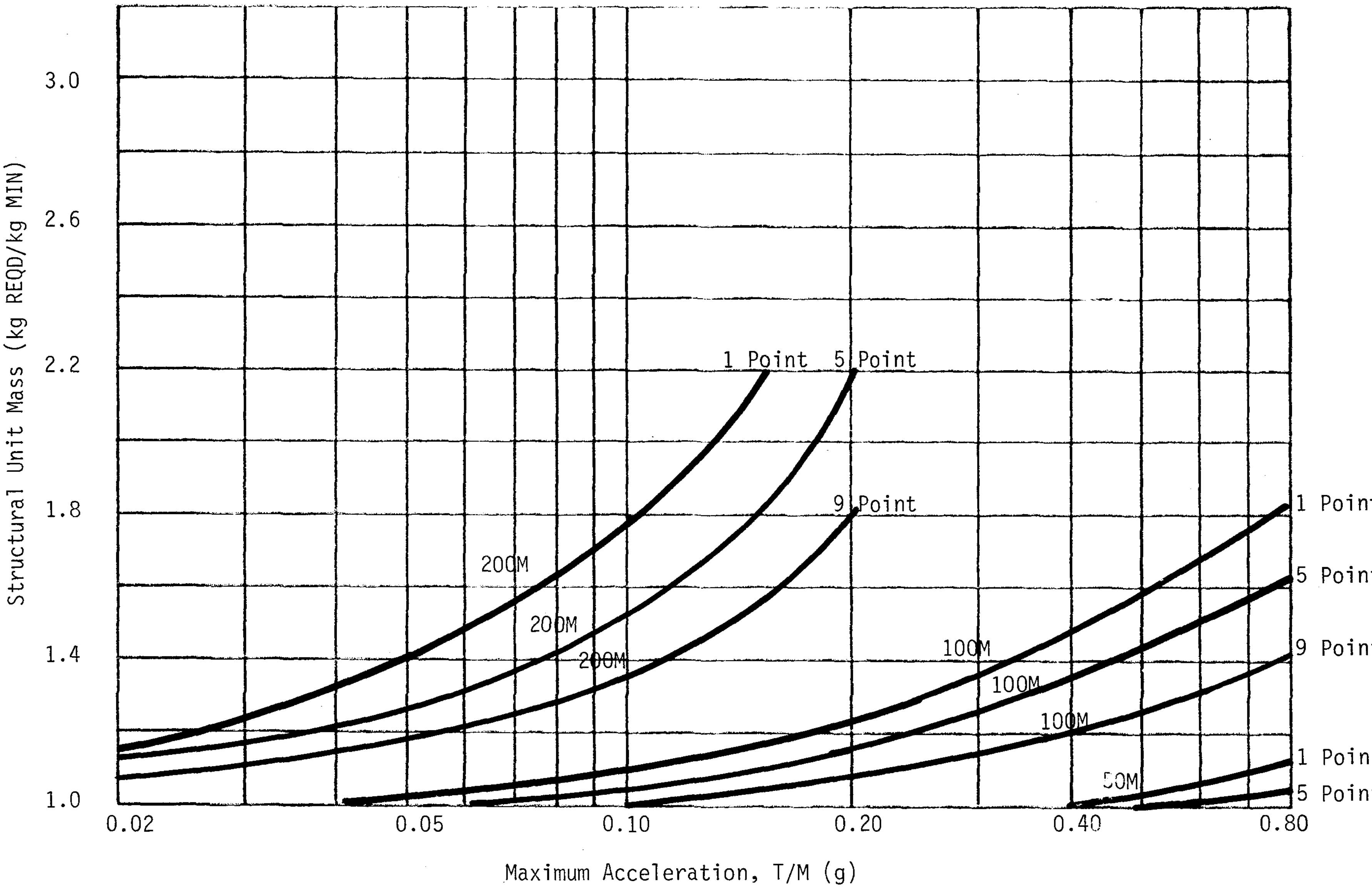


FIGURE III-31- 1, 5, AND 9 POINT THRUST IMPACT FOR 0.15kg/m^2 SURFACE DENSITY (HOOP AND COLUMN)

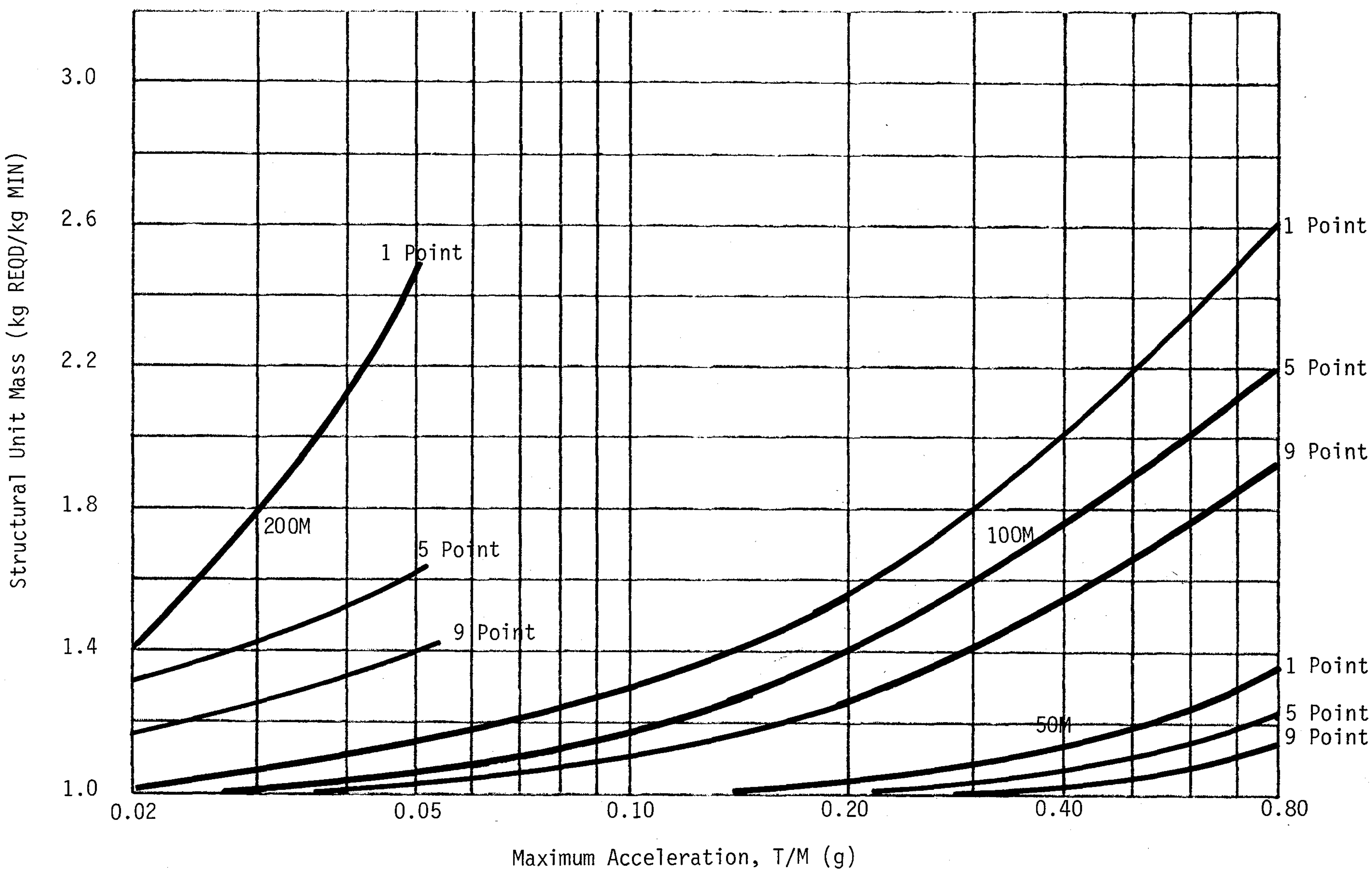


FIGURE III-32- 1, 5, AND 9 Point THRUST IMPACT FOR 0.40kg/m^2 SURFACE DENSITY (HOOP AND COLUMN)

IV. PROPULSION SYSTEM PERFORMANCE

A. Approach

In this task parametric analyses were performed to determine deliverable payload mass and engine burn times as a function of T/M, propulsion system performance, and number of perigee burns for transfer from low earth orbit (LEO) to geosynchronous earth orbit (GEO). This analysis was conducted within certain groundrules. The orbit transfer is from LEO (296 km circular orbit at 28.5° inclination) to GEO (35,900 km circular orbit at 0° inclination). The 28.5° plane change will occur at apogee. An initial startburn mass of 27,200 kg was assumed consistent with the STS capability with 2270.0 Kg for ASE. Other parameters considered are a specific impulse range of 300 to 450 seconds, a final thrust to mass ratio range of 0.01 to 1.0, and number of perigee burns ranging from 1 to 8.

A three-degree of freedom trajectory targeting and optimization program (GMAP) in which the entire trajectory can be simulated was used to develop the ideal velocity requirements. Certain options were taken into consideration to develop the trajectory strategy. The thrust segments were numerically integrated; with the coast segments propagated using Keplerian equations. Gravity turn steering was used during all perigee burns with constant yaw and pitch angles used at apogee to change the plane and circularize the orbit.

B. Results

Three thrust models; impulsive, constant thrust, and constant acceleration with ISP, number of burns, and T/M as parameters were studied as possible trajectory strategies. The cases studied are summarized in Table IV-1. Several conclusions can be drawn from the data associated with the trajectories identified in Table IV-1. First, multiple perigee burns can significantly reduce the ideal ΔV requirement for geosynchronous missions. This is illustrated in Figure IV-1. Utilization of mutiple burns lowers the required ideal velocity increment by reducing the gravity losses accumulated during the thrusting segments. Reduction of the gravity loss is a direct result of the negative to positive change in the flight path angle (FPA) over all but the first perigee burn (see Figure IV-2). Since the flight path angle is negative at the start of all multiple burns, the gravitational acceleration has a component that is in the same direction as the thrust vector. This effect causes the gravity losses to decrease prior to the osculating perigee passage. After perigee passage, the FPA becomes positive, and the gravitational acceleration causes a velocity loss in the normal sense of the term. However, the net loss is reduced by the counter-balancing contribution of favorable gravitational acceleration prior to perigee. This balancing effect is illustrated in Figure IV-2 by comparing the area above and below the zero FPA condition.

The second conclusion that can be drawn is that the constant acceleration propulsion mode offers advantages in ideal velocity requirements at certain T/M values over constant thrust cases for both 1 and 8 perigee burn transfers as illustrated in Figure IV-3. Constant thrust requires a 2% ΔV increase at low T/M using one burn and an 11% ΔV increase at low T/M using eight burns. In addition these data indicate that there is only minor ΔV variation between these propulsion modes at high T/M. This implies that for medium to high

TABLE IV-1 TRAJECTORY DATA SUMMARY

TYPE OF PROPULSION MODE	NUMBER OF PERIGEE BURNS	I_{sp} (SEC)	INITIAL T/M	FINAL T/M	ΔV* (M/S)	BURN TIME (HRS)	TRIP TIME (HRS)	PAYLOAD MASS (Kg)		
								λ = .75	λ = .85	λ = .95
IMPULSIVE	1	450	∞	∞	4232	0	5.3	4836	7469	9547
CONSTANT THRUST	1	450	0.10	0.2732	4435	0.8	5.6	4211	6918	9055
	1	450	0.06	0.174	4698	1.4	5.7	3441	6238	8446
	1	450	0.01	0.0337	5357	8.8	13.6	1706	4706	7076
	1	450	0.003	0.0108	5768	30.1	36.1	987	4073	6509
	2	450	0.01	0.032	5206	8.7	14.5	2082	503	7374
	4	450	0.01	0.033	4933	8.4	18.0	2795	5668	7936
	8	450	0.01	0.0281	4557	8.05	30.3	3849	6598	8768
	8	450	0.003	0.0101	5343	29.3	51.0	1740	4737	7103
	1	300	0.003	0.019	5562	23.6	29.6	3593	32	2893
	8	300	0.01	0.046	4501	6.5	30.3	1214	2130	4770
	8	300	0.003	0.0166	5046	22.8	46.8	2533	967	3729
	1	375	0.003	0.014	5621	27.2	33.2	1202	2140	4780
	4	450	0.136	0.0427	4756	5.9	17.1	3289	6104	8326
CONSTANT ACCEL.	1	450	0.1	0.1	4537	1.3	5.9	3908	6650	8815
	1	450	0.017	0.017	5457	8.9	13.3	1466	4496	6887
	1	450	0.01	0.01	5647	16.0	19.2	1021	4103	6536
	8	450	0.1	0.1	4287	1.2	29.1	4664	7317	9412
	8	450	0.03	0.03	4350	4.1	29.3	4469	7145	9258
	8	450	0.01	0.01	4817	13.5	30.9	3108	5945	8184

λ = MASS FRACTION

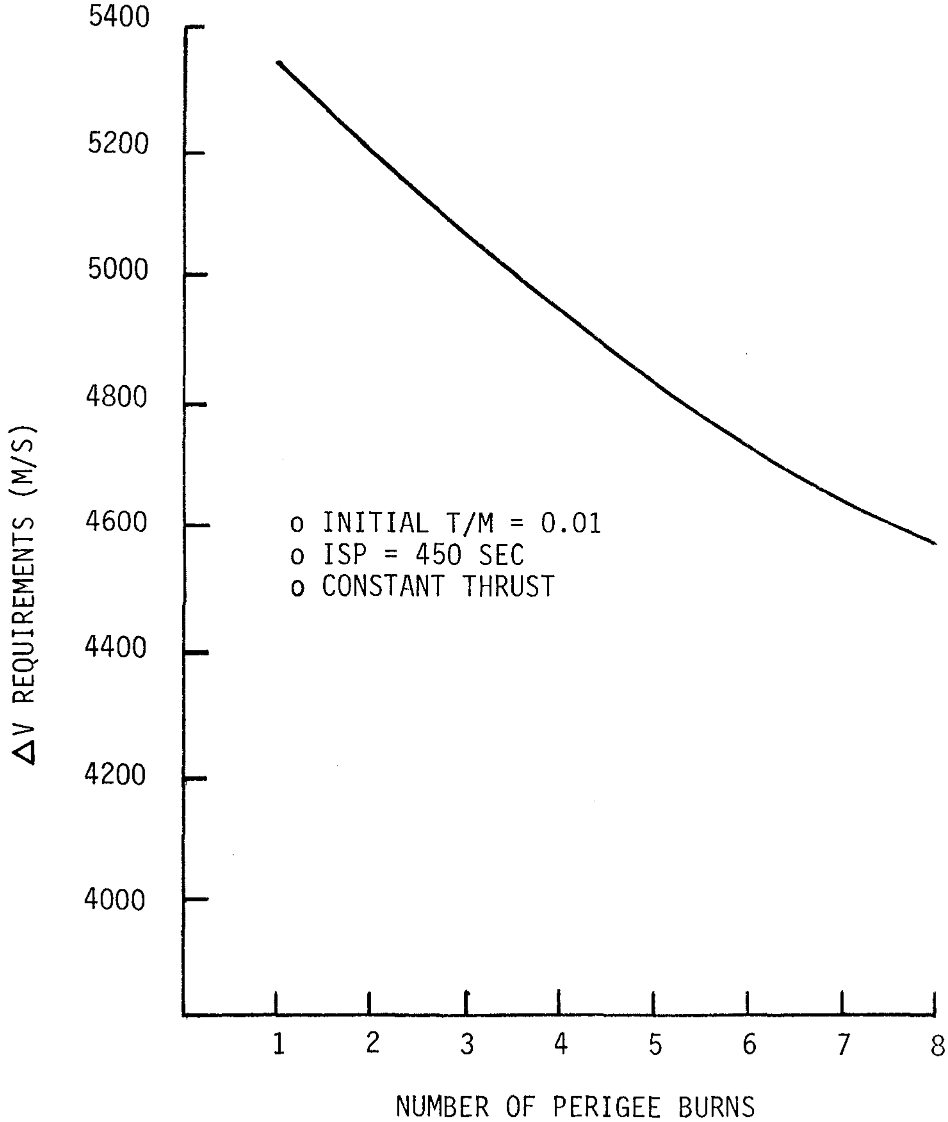


FIGURE IV-1 - VARIATION IN IDEAL VELOCITY REQUIREMENTS AS A FUNCTION OF THE NUMBER OF PERIGEE BURNS

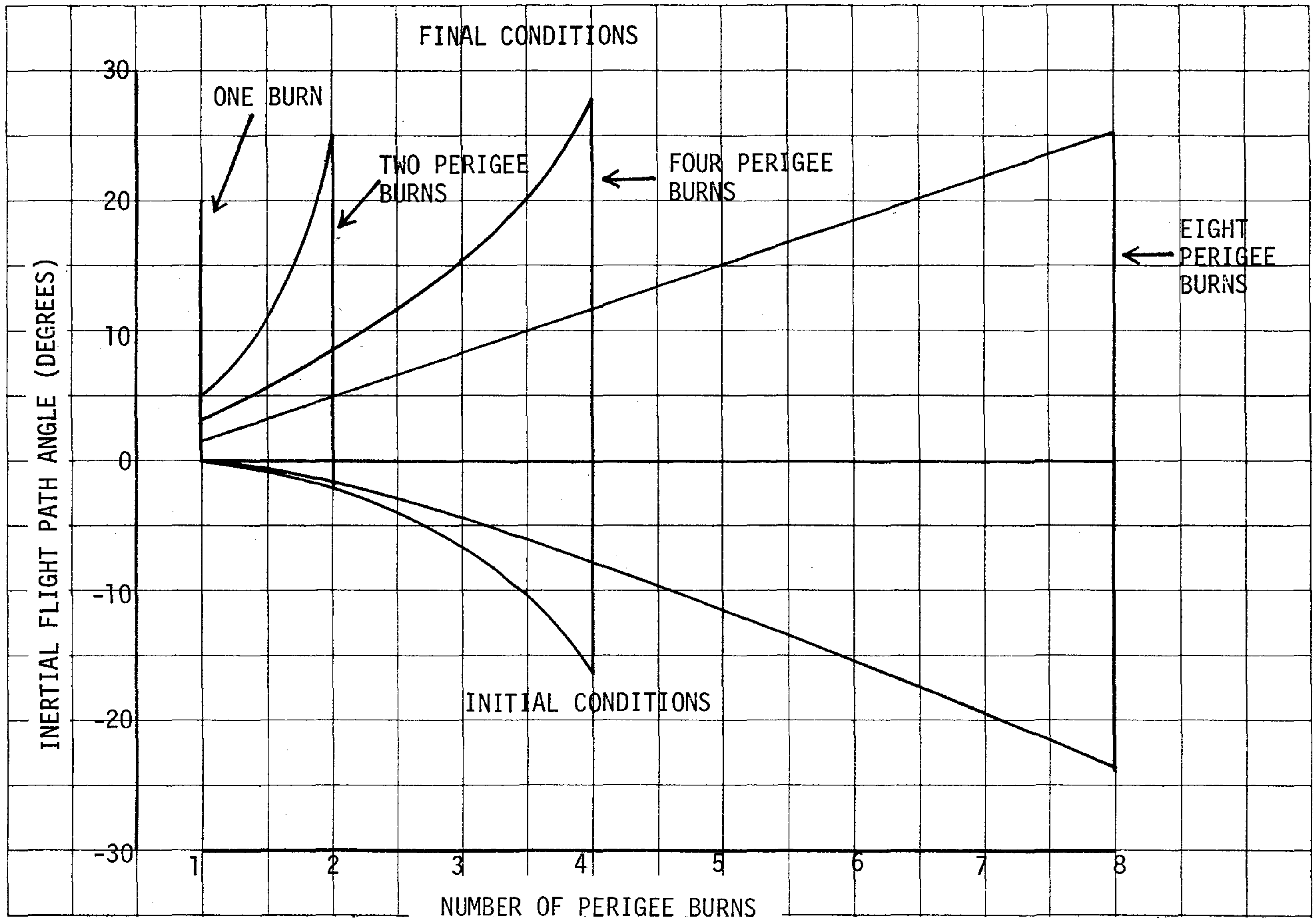


FIGURE IV-2 - APPROXIMATE FLIGHT PATH ANGLE ENVELOPES FOR THRUST SEGMENTS

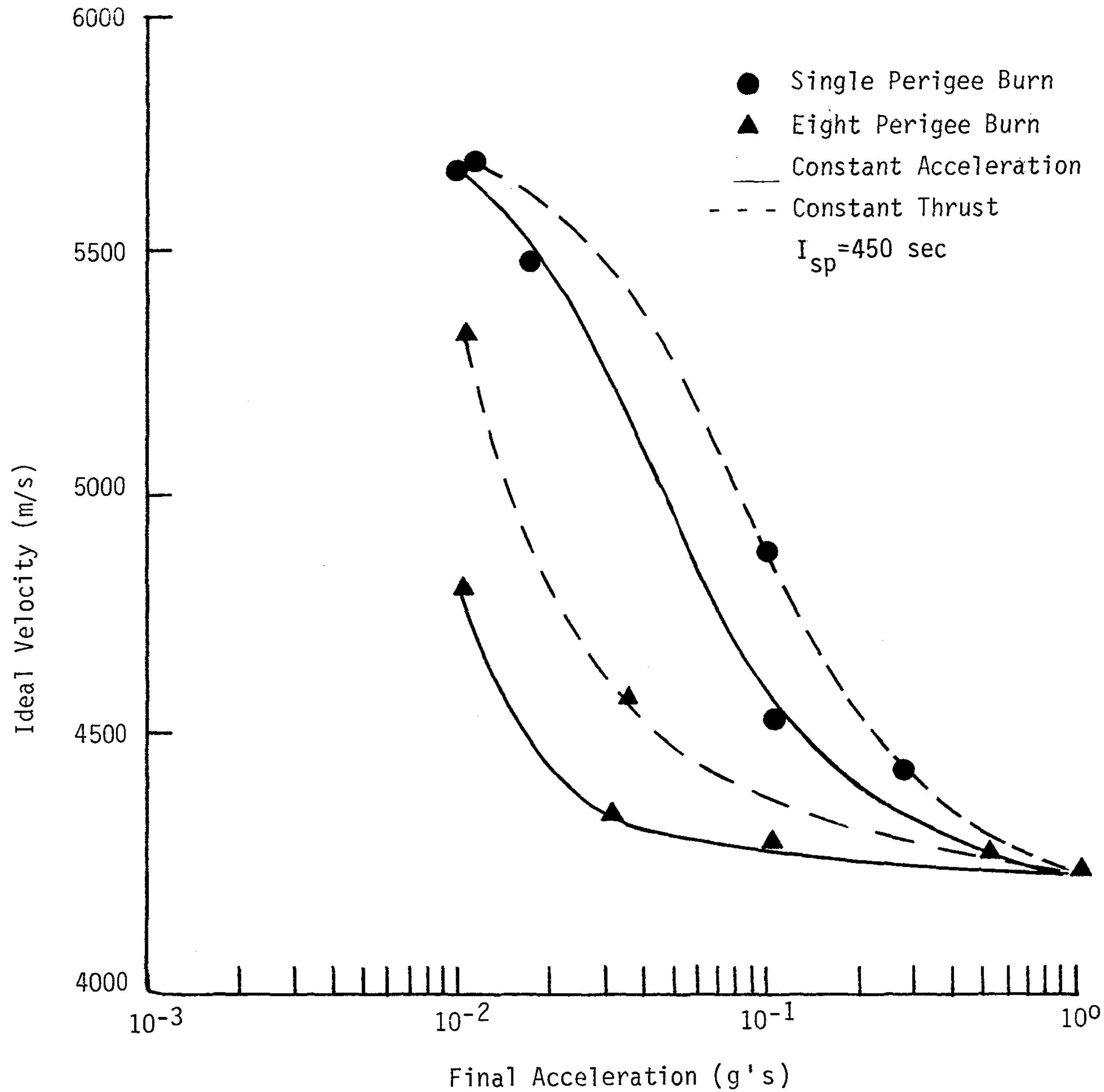


FIGURE IV-3- Ideal Velocity Requirements

thrust or extremely low thrust level applications, simplicity of the constant thrust propulsion mode would most likely offset the advantages of ΔV savings offered by the constant acceleration option. Figure IV-4 illustrates the comparisons of burn time as a function of thrust to mass for the constant thrust, constant acceleration modes for 1 and 8 burn transfer strategies. There are minimal differences between single and multiple burns burn time for both constant thrust and constant acceleration. However, constant thrust requires a 115% increase in burn times relative to constant acceleration at low T/M.

Figure IV-5 illustrates the comparisons of trip time for the two propulsion modes and the two perigee burn strategies. As shown by the curves constant thrust increases trip time by 65-88%, depending upon the number of perigee burns. With the use of high thrust multiple burns, coast time dominates burn time, however with the use of low thrust, burn time dominates. Therefore, trip time increases with the number of perigee burns due to the domination of coast time between burns. Also, multiple burn trip times for constant acceleration are nearly invariant to T/M.

Payload capabilities as a function of T/M with constant acceleration and constant thrust, 1 and 8 perigee burns and mass fraction as parameters are shown in Figure IV-6. Payload mass is essentially invariable at $T/M > 0.1$ g for eight perigee burns across the range of mass fractions from 0.75 to 0.95. For both 1 and 8 burn strategies payload mass does not equilibrate until $T/M \geq 1.0$ g for all mass fractions. Constant acceleration increases payload by 3-15% over constant thrust depending upon the number of perigee burns employed.

The numerical results obtained also indicated that required velocity increment (ΔV req) is relatively insensitive to the propulsion system Isp. The magnitude of this sensitivity for a final thrust to mass ratio of approximately 0.01 is presented in Figure IV-7. These data show that for a given final acceleration increased specific impulse results in a increased ΔV requirement. This trend is caused by the differences in mass consumption and burning times which cause gravitational losses, at least during the initial phases of the transfer, to be higher for the higher Isp systems. Comparison of the data in Figure IV-7 with the required ΔV shown in Figure IV-3 clearly demonstrates that Isp is not a major factor in the estimation of the mission ΔV requirements. In fact, analysis can show that Isp does not enter into the ΔV requirements for the constant acceleration mode. This is because in the constant acceleration case, Isp can be eliminated from the equations of motion. The impact of Isp only changes the vehicle weight time history; hence, deliverable payload; and not the ΔV requirement.

In summary, it is clear from these sensitivities that the T/M ratio is by far the principal driver in the trajectory design for low thrust systems with mass fraction as the second most important variable. The number of perigee burns has a significant impact on ΔV requirement, trip time, and delivered payload. The least important parameter appears to be Isp. However, changes in Isp still impact payload mass.

An intermediate orbit for an eight burn transfer is illustrated in Figure IV-8. Intermediate orbits one through eight represent the results of the perigee burns. The eighth orbit is the transfer orbit that delivers the payload to geosynchronous orbit. The thrusting areas are not shown so that

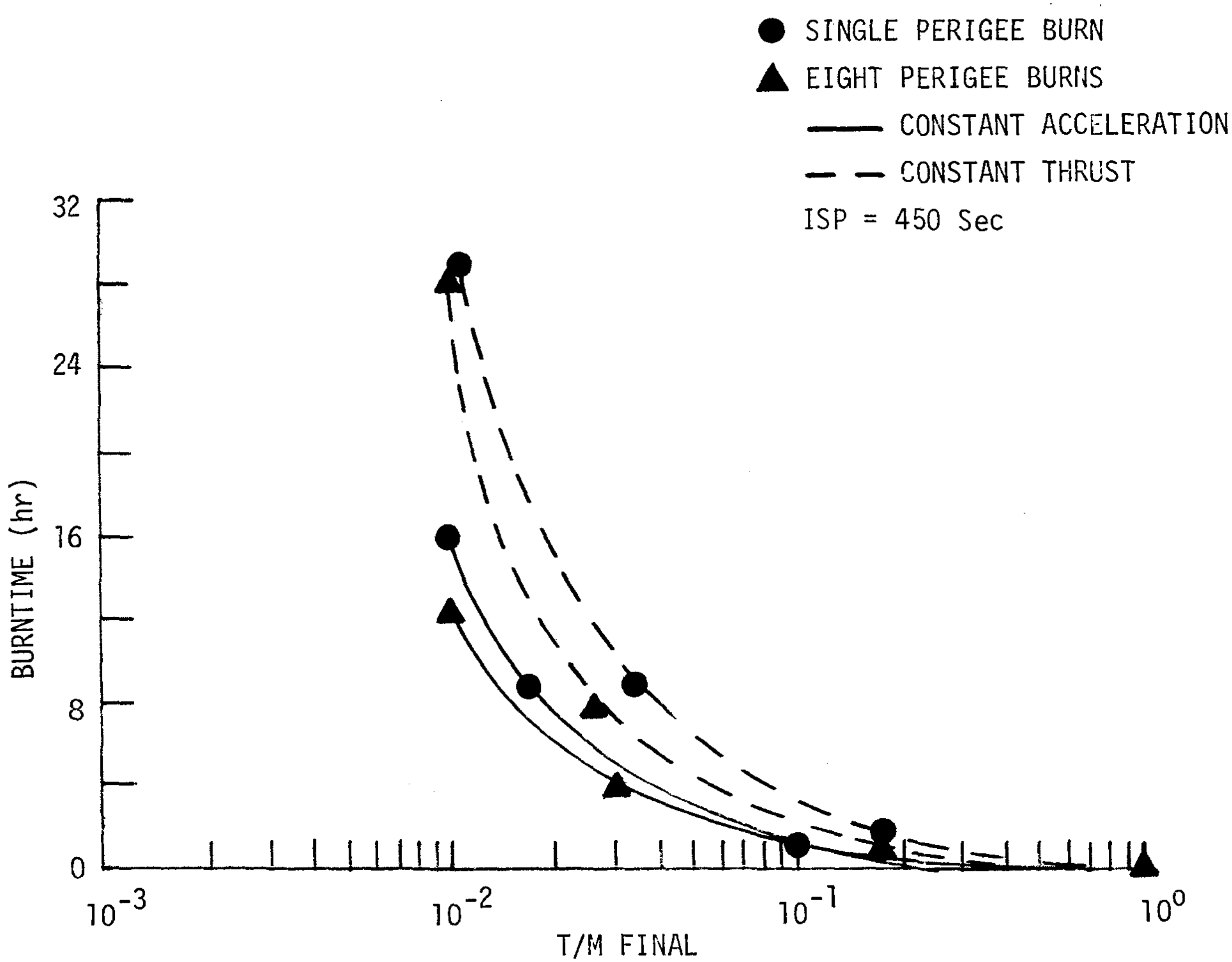


FIGURE IV-4 - BURNTIME REQUIREMENTS

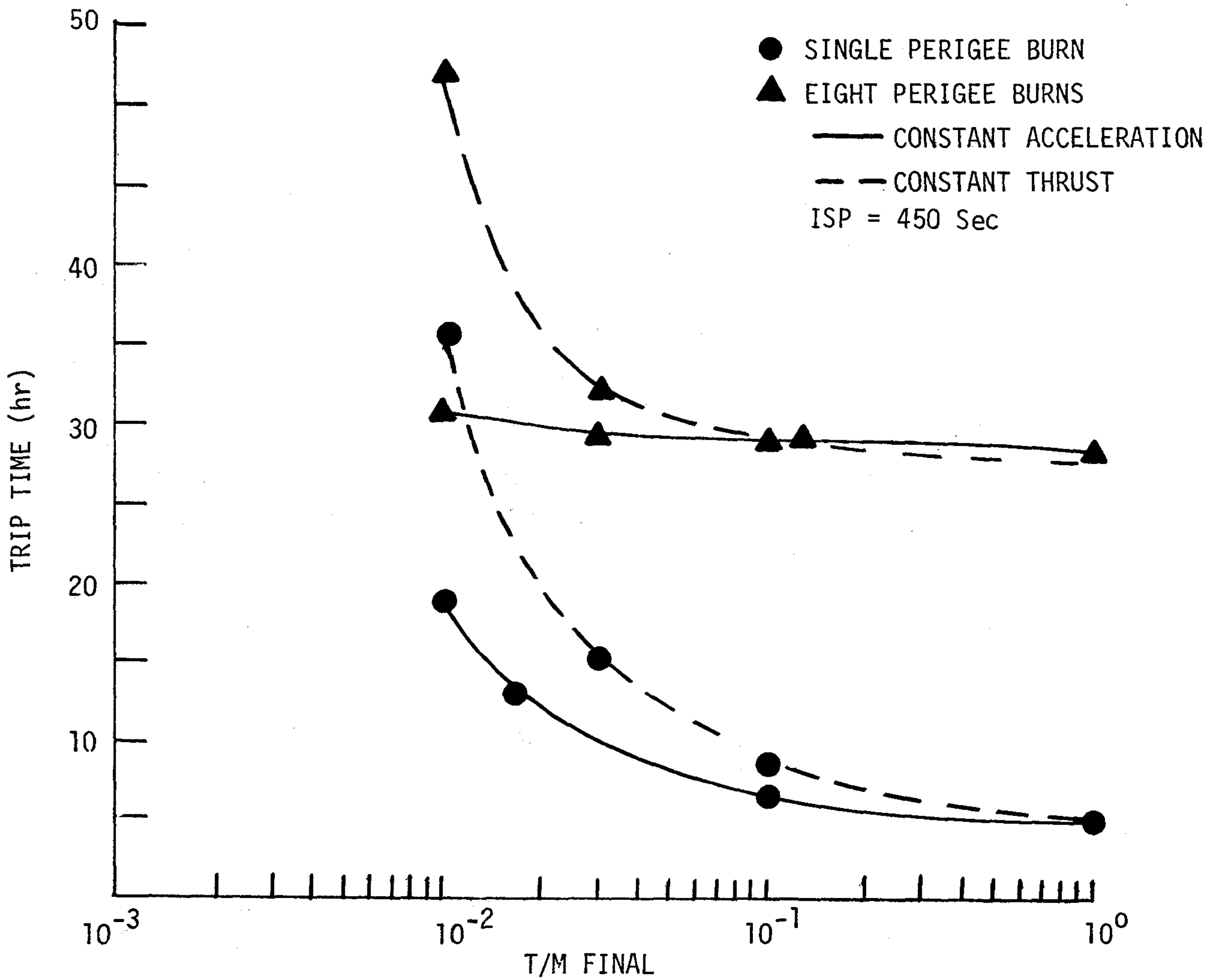


FIGURE IV-5 - TRIP TIME REQUIREMENTS

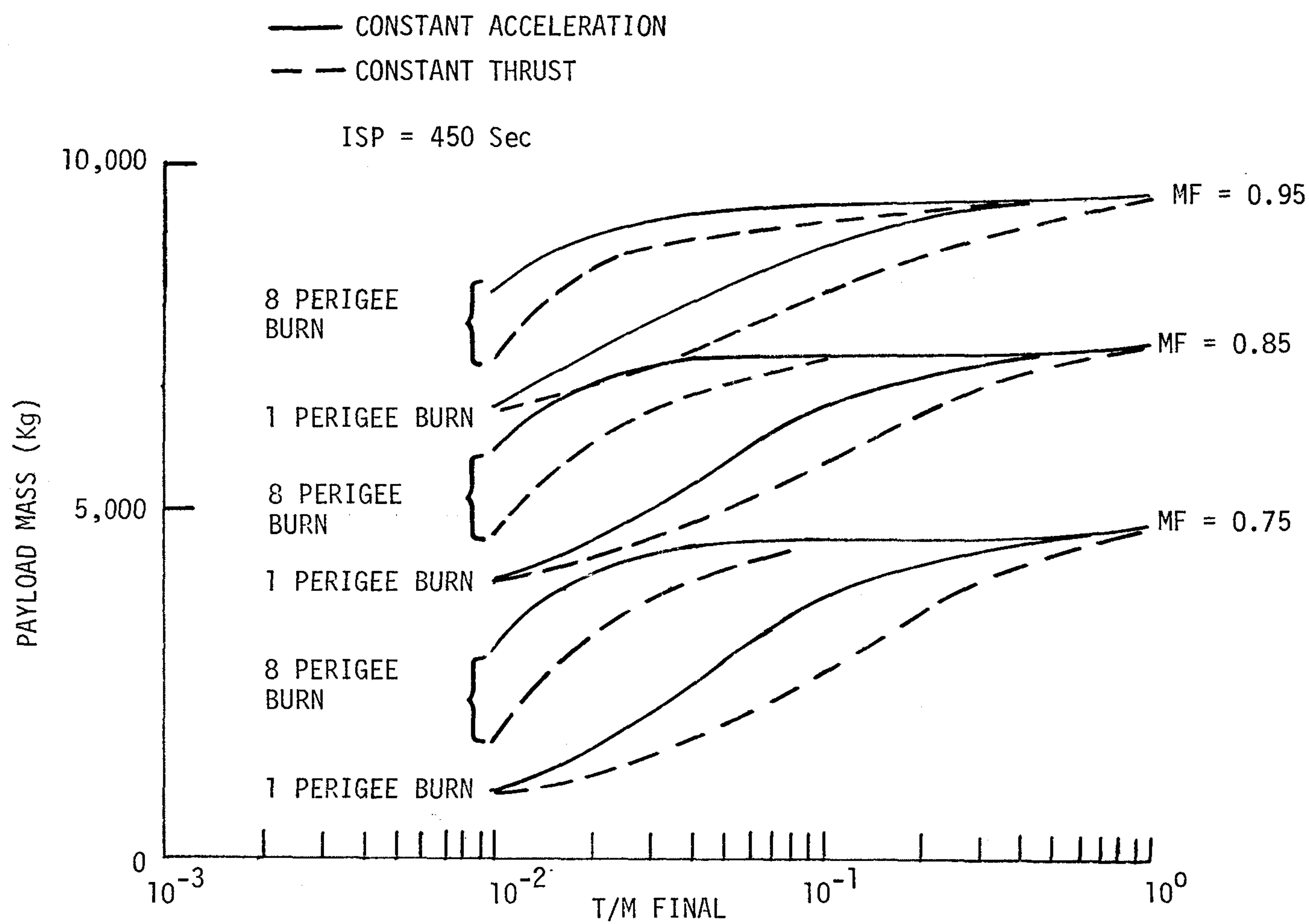


FIGURE IV-6 - PAYLOAD CAPABILITIES

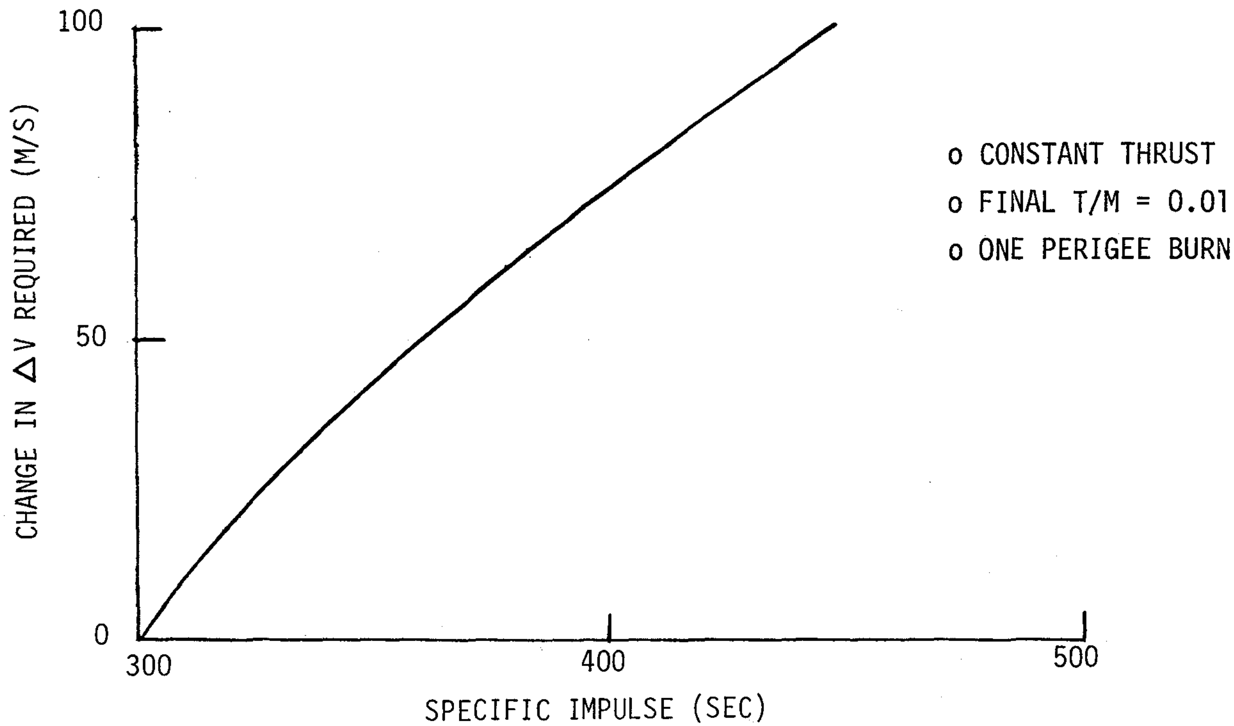
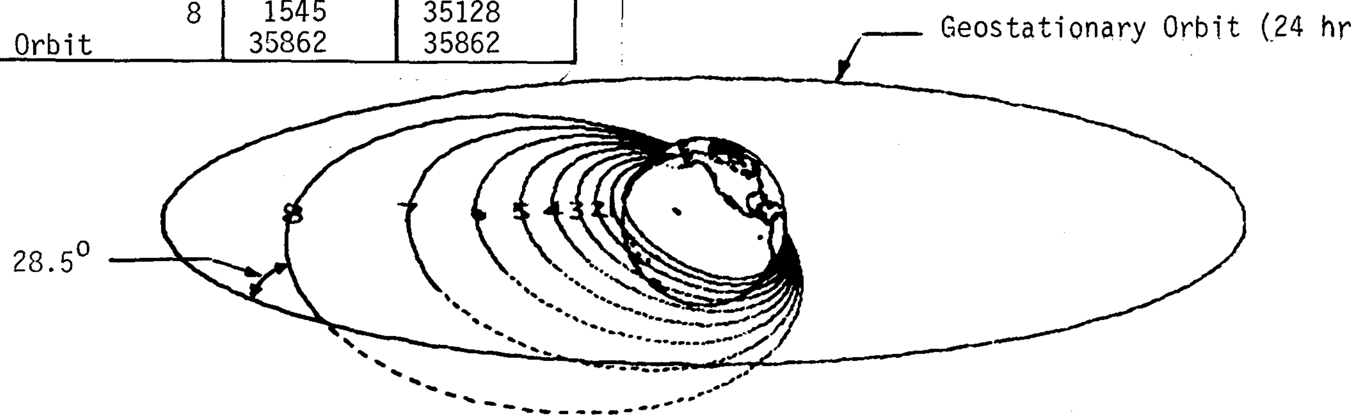


FIGURE IV-7 TYPICAL VARIATION IN ΔV REQUIRED AS A FUNCTION OF PROPULSION SYSTEM SPECIFIC IMPULSE

Initial Thrust to Mass = 0.01	Perigee Altitude, km	Apogee Altitude, km
Initial Orbit	296	296
Orbit After Burn 1	570	1269
2	796	2537
3	982	4699
4	1130	6425
5	1252	9477
6	1348	13875
7	1430	20674
8	1545	35128
Final Orbit	35862	35862



PLOT OF TWO ORBITS IN THE SAME PLANE R, FINAL ORBS

Figure IV-8 Sequence of Orbits for an Eight Burn Transfer Strategy
Viewpoint = 15°N, 135°W, $T/M_{Initial} = 0.01$

one can see the relative orbital growth as a function of the number of perigee burns. The sequence of apogee and perigee altitudes for these orbits are tabulated in the upper corner of Figure IV-8.

V. PROPULSION SYSTEM MASS AND VOLUME

A. Task Description

The objective of this task was to provide the characteristics of several primary propulsion stages that are packaged in the Orbiter cargo bay which are used to deliver LSS from low earth orbit (LEO) to geosynchronous earth orbit (GEO). Characteristics determined include mass fraction, length, diameter, and center of gravity position. The characteristics were determined parametrically as a function of thrust-to-mass ratio for four propellant combinations and three propellant masses over a selected mixture ratio range for both pump-and pressure-fed engines.

The loaded stage mass for which the parametrics were generated was based on the efforts of the previous tasks and in particular Section IV, Propulsion System Performance. This study was groundruled to begin with a Shuttle Payload Capability of 29486 Kg, of which 2270 Kg is depleted by the MMU (450 Kg) and ASE (1820 Kg). Thus the loaded stage mass plus payload delivery capability to geosynchronous orbit was based on 27,215 Kg total mass. Since stage delivery capability varies with mass fraction, specific impulse, thrust level, and number of perigee burns, the loaded stage mass must cover the range of stage delivery capability necessary to total 27,215 Kg. The thrust-to-mass ratio range, based on the results shown in Section III, Thrust and Thrust Transient Effects, is 0.01 g to 0.1 g. The three loaded stage mass values generated encompass the thrust-to-mass range which allowed the development of parametric plots of mass fractions, length, maximum diameter, and center of gravity versus final acceleration level. Mass statements were developed in sufficient detail so a realistic center of gravity and mass fractions were determined in consonance with the stage tankage configurations.

B. Stage Configuration Development

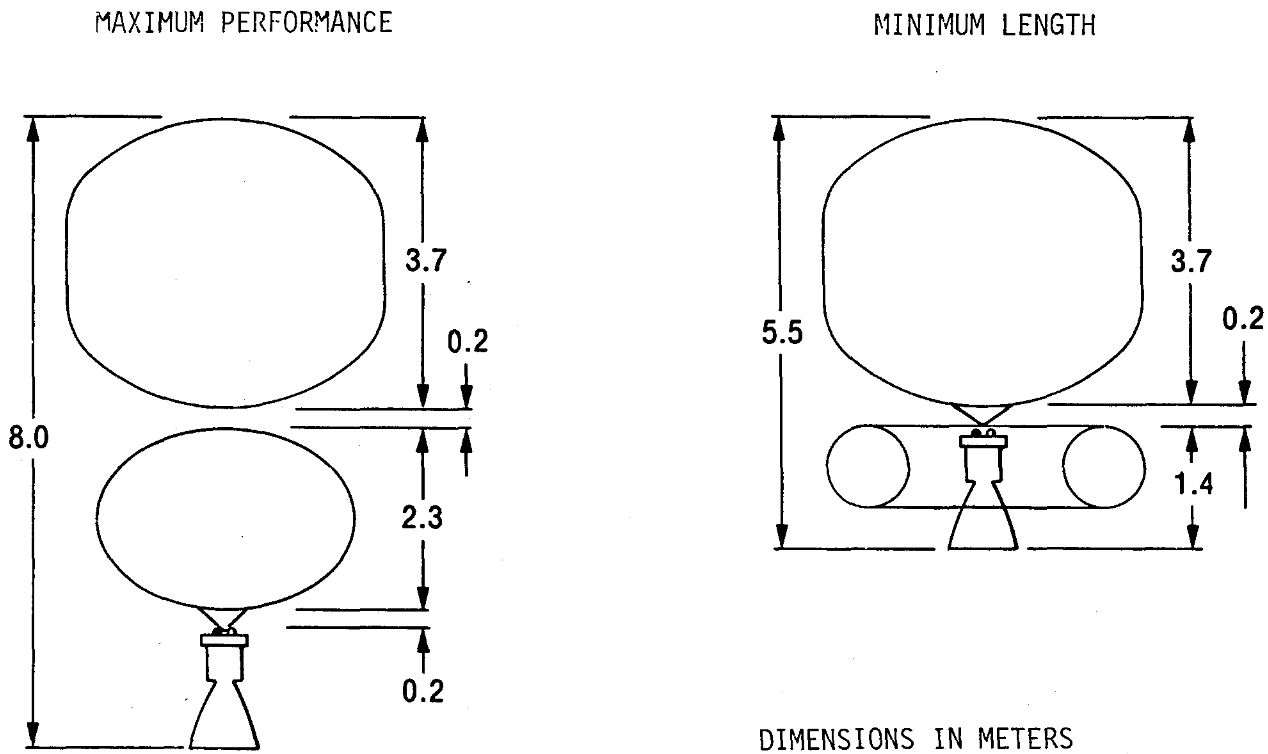
Stage configurations were developed for: oxygen/hydrogen, LO_2/LH_2; oxygen/methane, LO_2/LCH_4; oxygen/kerosene, LO_2/RP-1; and nitrogen tetroxide/monomethylhydrazine, N_2O_4/MMH. For each of the propellant combinations listed above, a maximum performance design and a minimum length design, each with pump-fed and pressure-fed engines, were evaluated.

Eight stage concepts (four propellants each with two tankage configurations) were developed for both engine types. Three mass statements corresponding to three propellant loads were developed for each configuration at three mixture ratios over the specified range, shown in Table V-1, for a total of 144 for each transfer strategy. The pump-fed and pressure-fed engine characteristics for the study were supplied by the LeRC project manager before the start of the task for all propellant combinations (see Appendix A).

1. Tankage Configuration

Maximum performance stage concepts were configured of cylindrical barrels with $\sqrt{2}$ dome ellipsoidal tank shapes for each of the four propellant combinations. The maximum performance configurations and selected tank shapes, Figure V-1, were based on study activities conducted in Low Thrust Chemical Orbit Propulsion System Propellant Management Study (NASA CR-165293); thus, maximum performance is consistent with Shuttle requirements and current tankage technology. The concept of maximum performance is designed around maximum delivery of payload mass to GEO. The maximum length available for

FIGURE V-I-TANKAGE CONFIGURATIONS



DIMENSIONS IN METERS
MAXIMUM OUTSIDE DIAMETER = 4.3 m
DIMENSIONS ARE TYPICAL

TABLE V-1 - PARAMETRIC RANGE OF MIXTURE RATIO

Propellant Combination	Mixture Ratio Min.	Int.	Max.	Comments
LO_2/LH_2	5.0	6.0	7.0	
LO_2/LCH_4	3.4	3.7	4.0	These mixture ratios are associated with all tankage configurations and pump-fed pressure-fed engine concepts.
LO_2/RP-1	2.8	3.0	3.2	
N_2O_4/MMH	1.8	2.2	2.6	

maximum performance tankage and payload ranges from 16.22 to 16.46 meters, dependent upon propellant combination, was determined from Orbiter restraints presented in Figure V-2.

Minimum length configuration, also presented in Figure V-1, while providing for larger payload volume, requires more tankage mass and, therefore, limits the overall deliverable payload mass. The increased tankage mass is attributed to the use of a toroidal tank which weighs approximately 30 to 35% more than an ellipsoidal tank in the 13,600 to 15,870 Kg oxidizer propellant load range. For all minimum length cases analyzed, the oxidizer, is located in the toroidal tank. The advantage of the toroidal tank is the increased available orbit transfer vehicle payload length due to the shorter toroidal tank and embedding the engine within the toroid. The maximum available length for a minimum length tankage and payload is 15.24 meters as shown in Figure V-2.

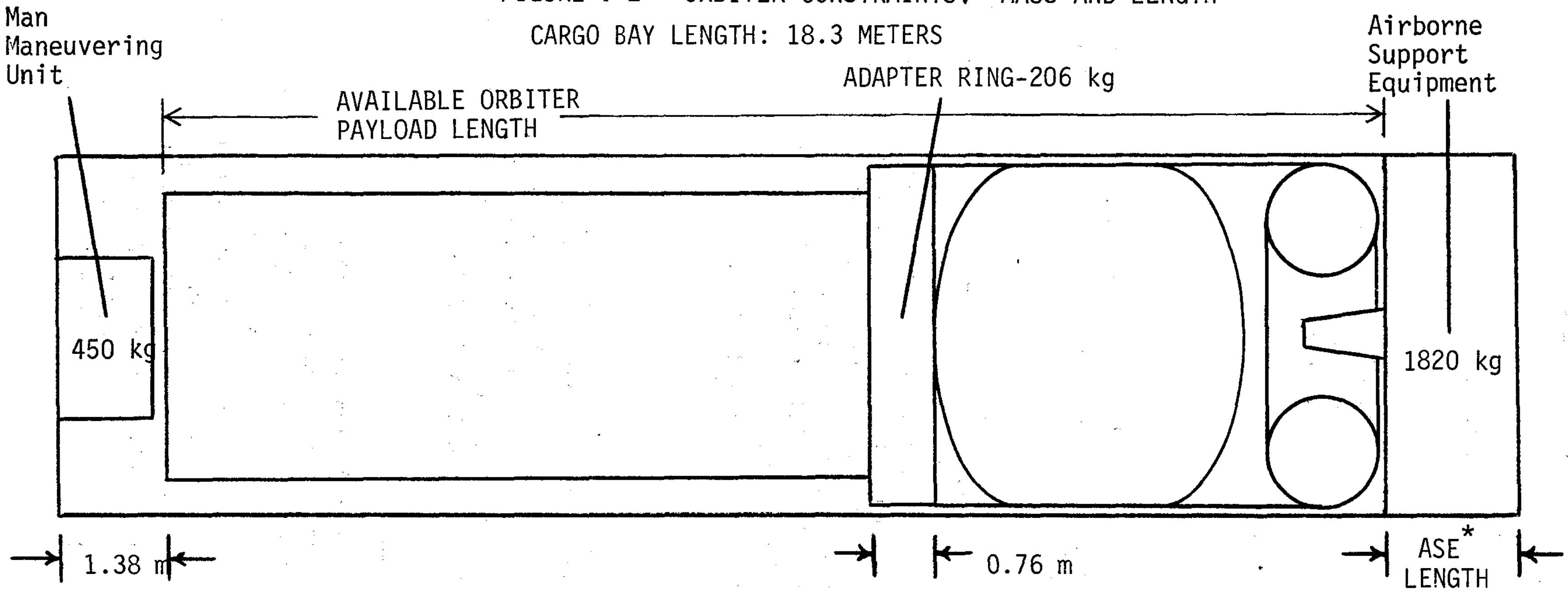
2. Maximum Diameter

Starting with the maximum cargo bay diameter of 4.57 m, an allowable stage diameter of 4.42 m was determined from inputs of DOD/STS Payload Integration Contract (F04701-77-00183). With a shell thickness of 1.32 cm, a clearance between the shell and insulation of 2.54 cm, and a maximum insulation thickness of 3.56 cm, the maximum inside diameter of the tank is limited to 4.26 meters. The tank material is aluminum 2219-T87.

3. Lift-Off Propellant Densities

Propellant conditions at lift-off and during the no vent period of Shuttle ascent (T + 90 seconds) have been derived under Contract NAS3-21954, Low Thrust Chemical Orbit to Orbit Propulsion System Propellant Management Study (NASA CR-165293). The analysis performed accounted for changes in cryogenic propellant densities due to boiling of the propellant during launch. For the initial tank sizing in Section V-B, the propellants were considered to be at saturation conditions. Since the heat leak to the propulsion system during the ground hold time and launch is large enough to produce boiling in the cryogens, the decrease in density must be integrated into the system sizing. These analyses apply to the LO_2/LH_2, LO_2/LCH_4, and LO_2/RP-1 propellant combinations.

FIGURE V-2 - ORBITER CONSTRAINTS: MASS AND LENGTH



*ASE LENGTH FOR 75^0 DEPLOYMENT OF ORBITER PAYLOAD

MAXIMUM PERFORMANCE: TANKAGE	LO_2/RP-1	-0.46 m
	LO_2/LCH_4	-0.61 m
	LO_2/LH_2	-0.70 m
	N_2O_4/MMH	-0.70 m

MINIMUM LENGTH: ALL PROPELLANT COMBINATIONS -1.67 m
TANKAGE

These densities and the associated tank pressure (124 KN/M^2 nominal, 165 KN/M^2 maximum) and time line (top to T-4 minutes, no venting until T + 90 seconds) were applied to the systems for this program. The results are summarized below:

	DENSITY
LH_2	67.1 Kg/M^3
LO_2	1106.5 Kg/M^3
LCH_4	411.0 Kg/M^3

For RP-1, N_2O_4, and MMH, densities consistent with 21°C propellant temperature were used:

RP-1	805.8 Kg/M^3
N_2O_4	1433.9 Kg/M^3
MMH	870.2 Kg/M^3

4. Insulation Systems

Multilayer (MLI) and spray-on foam insulation (SOFI) systems have been evaluated for cryogenic propellants (LO_2, LH_2, LCH_4) in NASA CR-165293. The results show that for all cases ranging from 445.0 N thrust (0.005g) to 4448.0 N (0.05g), the MLI system are lighter than comparable SOFI systems. Therefore, MLI was used as the baseline insulation system for this program.

C. Stage Mass Statements

Mass statements for each stage concept were generated at minimum intermediate, and maximum mixture ratios for a minimum of three propellant loads. The stage masses were based on an iterative scheme utilizing the ideal velocity equation and the engine data supplied by LeRC. The details of the mass statements are presented in Table V-2 through V-4, where Table V-2 shows the fixed masses for all propulsion systems. The remaining tables represent masses which were assigned specifically for cryogenics or storable propellants with either maximum performance or minimum length stages. Where masses are variable with stage mass, a range of masses is given. A 10% contingency factor was applied to all stage mass results. However, this percentage is not included in the values presented in Tables V-2, V-3, and V-4. Many of the mass items are self-explanatory, but the following ground rules for some of the components had to be set forth to provide uniform values:

Propellant Load:

Usable - calculated from ideal velocity equation;
Performance Reserve - 2% of usable based on previous Centaur data;
Start/Shutdown Losses - 1 to 2.3 Kg loss per burn, dependent upon engine thrust, at ignition (for cryogens) including chilldown and engine tailoff losses;
Boiloff - conservative estimate of losses from propellant evaporation due to thermal energy leaks (calculated for each transfer strategy);
Trapped Propellants - consists of the amount of propellant necessary to fill the feed lines and engine;
Expulsion Efficiency - 98%, the efficiency associated with draining the propellant from the tank; and
Loading Accuracy - 0.5%, percentage assigned to accuracy of loading equipment.

TABLE V-2 - COMMON MASSES FOR ALL VEHICLES (Ref. V-1)

ITEM	MASS (Kg)	Remarks
Avionics		
Data Management and Instrumentation	71.7	
Guidance and Navigation	69.8	
Communications	32.8	
Power (Fuel Cells)	181.4	
Propulsion		
ACS Engine (Bipropellant)	68.0	16 @ 445 N
ACS Support	152.7	4 modules @ 11 kg-sec each estimate
ACS Booms and Controls	45.3	
Nonusable Propellant		
Trapped Propellant - ACS	12.7	trapped and outage
Propellant Reserves - ACS	17.2	10% of usable
Propellant Fluids Loaded		
Attitude Control	186.8	
Shuttle Interface Accomodation	1820.0	
ACS	174.1	
Spacecraft Interface Equipment		
Retaining Ring	205.9	
Airborne Support Equipment		
Shuttle Interface Accomodation	1820.0	
MMU	450.0	

TABLE V-3 - CRYOGENIC PROPELLANTS MASS STATEMENTS (Ref. V-2)

ITEM	MASS (Kg) MAXIMUM PERFORMANCE	MASS (Kg) MIN LENGTH	
Stuctures			
Body structure	353-376	328-345	
Thrust structure	11	20-23	
Equipment mounting	41	41	
Umbilical	15	15	
Shuttle I/F equipment	48	48	
Thermal Control			
Purge System	67	67	
Thermal Control	57	57	
Propulsion			
Fill vent & drain	244	270	
Trapped propellant-main	32	64	
Trapped gas (vapor)	92-103	92-103	
Propellant outage (max)	49-55	47-56	0.25% of usable

TABLE V-4 - STORABLE PROPELLANT MASS STATEMENTS (Ref. V-3)

ITEM	MASS (Kg) MAXIMUM PERFORMANCE	MIN LENGTH	
Structures			
Body structure	191-388	349-513	
Thrust structure	11-13	11-30	
Equipment mounting	29	29	
Umbilical	4	4	
Shuttle I/F equipment	26	26	
Thermal control	33-124	49-124	
Propulsion			
Fill vent & drain	70	91	
Trapped propellant main	7	20	
Trapped gas (vapor)	103-116	103-116	
Propellant outage(max)	48-55	48-55	0.25% of usuable

Structures:

Fuel and Oxidizer Tanks - the primary metal enclosure in which propellant is contained excluding thermal protection, support structure and transmission lines.
Body Structures - the basic lattice structure of the stage which acts as the primary support for the stage;
Thrust Structure - the structural support used to attach the engine to the body structure including engine gimbaling assemblies;
Equipment Mountings - the devices used to mount stage equipment i.e. Avionics, fuel cells, batteries, etc. to the body structures;
Umbilicals - all connection cables or lines that detach from the vehicle before operation but that are payload chargeable weight;
Shuttle I/F (Interface) Equipment - all fittings connectors and other equipment (excluding umbilical and ASE) that the stage requires to interface properly with shuttle and are not deployable after use; and
Payload Separation Module - the equipment used to separate the payload from the stage after it is positioned.

Insulation:

Fuel and Oxidizer - the primary blanketing material that covers the tanks and feedlines (MLI) as applicable.

Purge Systems:

The helium storage and delivery system used to purge the insulation of air to prevent liquid air pumping during the prelaunch period.

Thermal Control:

The active system used for control of propellant temperature that uses vented propellant, or other propellant conditioning methods.

Avionics:

Data management and instrumentation includes the on-board digital logic-service functions of on-board checkout, redundancy control, data transfer, command decoding/distribution, data sampling/conditioning/ accumulating/storage, caution and warning, timing, interbox/vehicle data transfer, coding/decoding, and computer services.

Guidance and Navigation control consists of a skewed redundant strapped-down inertial measurement unit, star tracker, horizontal sensor, portions of the data management subsystem, integrated hydraulic actuators, and attitude-control valves and nozzles.

Communications include a S-band communications system which utilizes the airborne electronically steerable microwave phased array. The general purpose television camera, command decoder and command distribution and driver are additional components.

Power includes two fuel cells (2.0 kw avg. - 3.5 kw peak), one auxiliary battery (25 amp-hr), 28 V. Power system, dual electrical power and distribution system, conventional power distribution with data bus control, solid state power control, fuel cells to be started after release from orbiter, emergency shutdown capability from orbiter, monitoring capability from orbiter, dedicated reactant tanks, and fail operate/fail safe.

Sufficient detail is provided in the mass statements so that realistic assessments of mass fractions are derived from stage propulsion data.

D. Stage Parametric Analysis

To help generate stage propulsion data, a propulsion sizing computer program, PROP was used. The discrete elements contained in the program are shown in Figure V-3 and are briefly described in the following paragraphs.

Internal calculations in the program include:

1) Pressurant mass, regulated or blowdown system,
2) Propellant mass, from required ΔV,
3) Propellant tank mass and size,
4) Mass of the structure.

Inputs to the program are: engine performance and mass data; tankage details such as shape, single, dual or multiple tanks; ΔV; mission time line, propellant properties; insulation properties; pressurization system type; performance; etc.

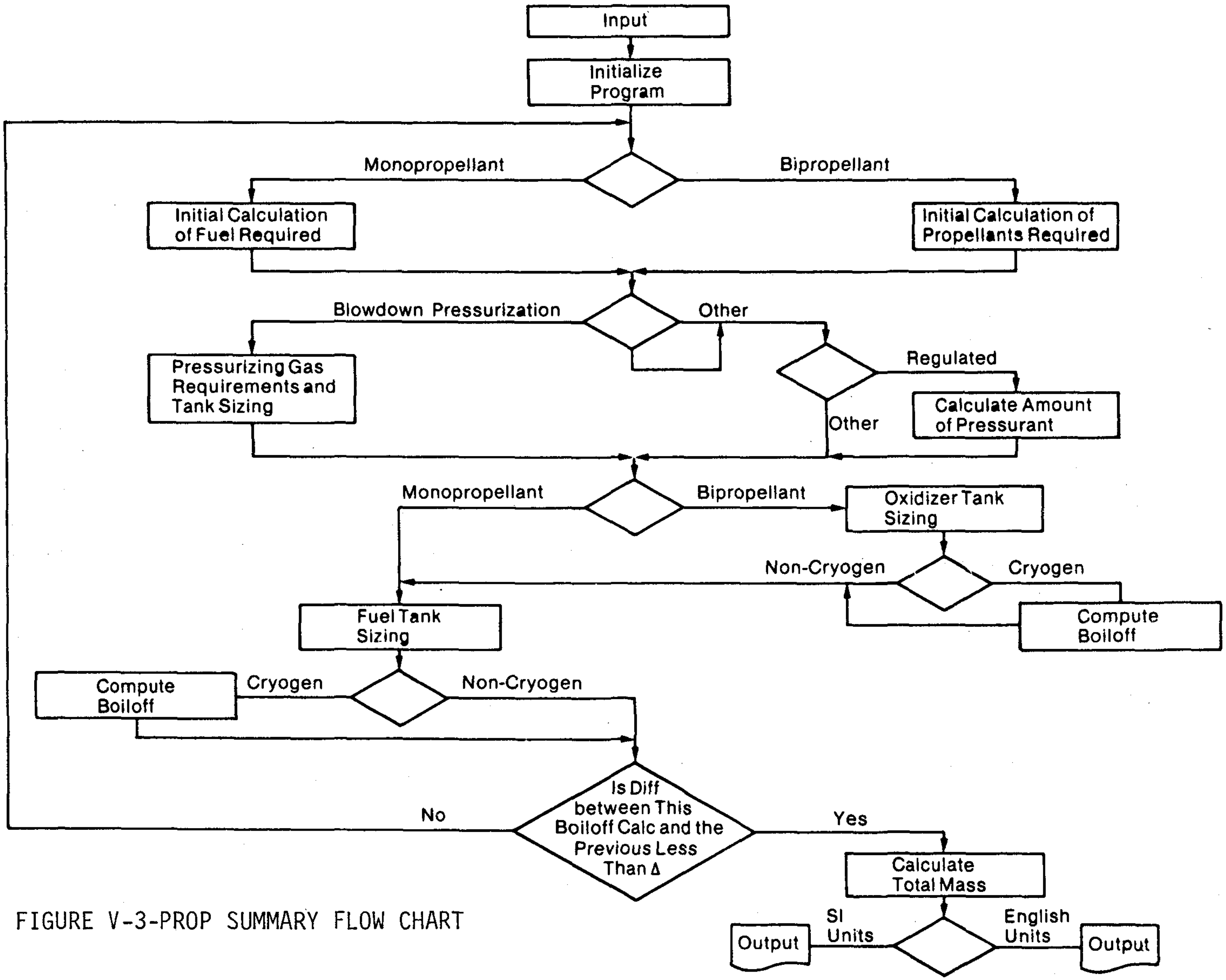


FIGURE V-3-PROP SUMMARY FLOW CHART

A sample output of PROP is shown in Figure V-4. The output sheets for the remaining cases are shown in Appendix B. The total mass of a number of items listed in Tables V-2, V-3, and V-4 are output by the prop program under the heading of (1) components and lines and (2) engine mounts and supports. A breakout of these items is shown in Table V-5 for this sample case. The values for trapped propellants consider propellant in the feed line, a 98% expulsion efficiency, and a loading accuracy of 0.5%. The parameters extracted from the mass statements are the total stage wet system mass, mass fraction, and stage length.

The stage length was determined for maximum performance and minimum length tankage configurations. The equation for stage length of maximum performance is: Stage Length = Fuel Tank Length + Oxidizer Tank Length + 30.4 cm Clearance + Engine Length.

The equation for minimum stage length is: Stage Length = Fuel Tank + 15.2 cm Clearance + Oxidizer (Torodial) Tank Height + the length of the engine that exceeds the Oxidizer Tank Height (Embedded Engine)

The engine lengths were determined from the supplied LeRC engine data in Appendix A at the corresponding thrust level of the stage being considered.

With lengths and masses of the individual components available, center of gravity calculations were completed with the nose of the Orbiter as the reference.

Based on the stage mass statements and stage design details, parametric data were generated for stage length, mass fraction, stage mass, and center of gravity versus propellant mass and thrust-to-mass for both pressure-fed and pump-fed engines.

E. Stage Parametrics Versus Thrust-To-Mass:

Stage parametric data are shown as a function of final thrust-to-mass ration in Figures V-5 through V-16. The figures are arranged as follows:

Figure V-5 through V-8: Stage Mass
Figures V-9 and V-10: Mass Fraction
Figures V-11 and V-14: Stage Length
Figure V-15 and V-16: Center of Gravity

It can be observed from the Figures that the total matrix of variables was not duplicated for all permutations since the basic trends and resultant conclusions can be derived from the primary set of propulsion system data.

F. Stage Parametrics Results

1. Mixture Ratio

Review of stage characteristics data for an 8 perigee burn, constant acceleration transfer exposed mixture ratio as an ineffective parameter for LO_2/LCH_4, $LO_2/RP\text{-}1$, and N_2O_4/MMH. Variation of stage length, mass fraction and stage mass with mixture ratio was less than 3% from the nominal mixture ratio for all configurations. Thus, stage characteristics for the above propellants are plotted versus thrust/mass at their corresponding

FIGURE V-4-SAMPLE OUTPUT OF PROP

9 BURNS, CONSTANT ACCELERATION, T/M=0.015

```
    LH2/LO2  MIN LENGTH  PUMP FED                 MR=6

VEHICLE MASS  =27215.5 KG    DELTA V=  4480.6 M/S   AVE. ISP=4432.4 N-S/KG

TOTAL PROPELLANT                           18208.04 KG
  USABLE FUEL                    2450.90
  USABLE OXIDIZER               14705.41
  FUEL TRAPPED                     97.70
  OXID TRAPPED                    571.27
  FUEL START-S/D LOSSES             7.26
  OXID START-S/D LOSSES             7.26
  FUEL BOILOFF                    148.65
  OXIDIZER BOILOFF                219.58

OXIDIZER TANKS (NO.= 1)                      104.79
 (TOROIDAL)
  INNER DIA=     1.449 M
  OUTER DIA=     4.267 M
  HEIGHT    =    1.409 M
  VOLUME    =   13.999 M3
  AVG THK   =   .00064 M
  FS = 1.50,  FNOP= 1.50

FUEL TANKS (NO.= 1)                          156.50
 (CYLINDRICAL/SQRT(2) ELLIPTICAL)
  DIAMETER=    4.267 M
  LENGTH  =    3.784 M
  VOLUME  =   39.735 M3
  DOME THK=   .00069 M
  CYL THK =   .00114 M
  FS = 1.50,  FNOP= 1.30

PRESSURANT                                   15.886

PRESSURANT TANKS (NO.= 1)                     85.16
  DIA=     .8985 M
  VOL=      .380 M3
  THK=    .00758 M
  FS = 1.50,  FNOP= 1.10

FUEL TANK INSULATION                          99.67
OXIDIZER TANK INSULATION                      58.22

ENGINES (NO.= 1)                              40.82

COMPONENTS AND LINES                         589.67
ENG. MOUNTS,SUPPORTS                        1293.65

TOTAL WET SYSTEM MASS                       20652.4
TOTAL BURNOUT MASS                           3113.3
   (INCL.NON-USABLE PROP. AND GAS)

MASS FRACTION                                  .831
TOTAL IMPULSE                          76047159.3 N-S

            PRESSURE SCHEDULE(N/M2  )   AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =   .2482E+08    INITIAL CHAMBER PRESSURE =0.
INITIAL OX SYS PRESSURE   =   .1517E+06    FINAL OX SYS PRESSURE    =  .1517E+06
INITIAL FU SYS PRESSURE   =   .1517E+06    FINAL FU SYS PRESSURE    =  .1517E+06
```

Table V-5 - Sample Breakout of Components and Lines, and Engine Mounts and Supports

- LO_2/LH_2, minimum length, pump-fed, T/M = 0.015, MR = 6.0
- 8 perigee burn, constant acceleration

	kg
Fill Vent and Drain	270.0
ACS Engine (Bipropellant)	68.0
ACS Support	152.7
ACS Booms and Controls	45.3
Subtotal	536.0
10% Contingency	53.6
Components and Lines	589.6
Body Structure	333.4
Thrust Structure	21.3
Retaining Ring	205.9
Equipment Mounting	41.0
Umbilical	15.0
Shuttle I/F Equipment	48.0
Thermal Control	
Purge System	67.0
Control	57.0
Avionics	
Data Mgnt. and Instrumentation	71.7
Guidance and Navigation	69.8
Communications	32.8
Power (Fuel Cells)	181.4
Nonusable Propellant	
Trapped Propellant (ACS)	12.7
Trapped Helium (Main and ACS)	1.8
Propellant Reserves (ACS)	17.2
Subtotal	1176.0
10% Contingency	117.6
Eng. Mounts, Supports Total	1293.6

FIGURE V-5 STAGE MASS VERSUS THRUST-TO-MASS

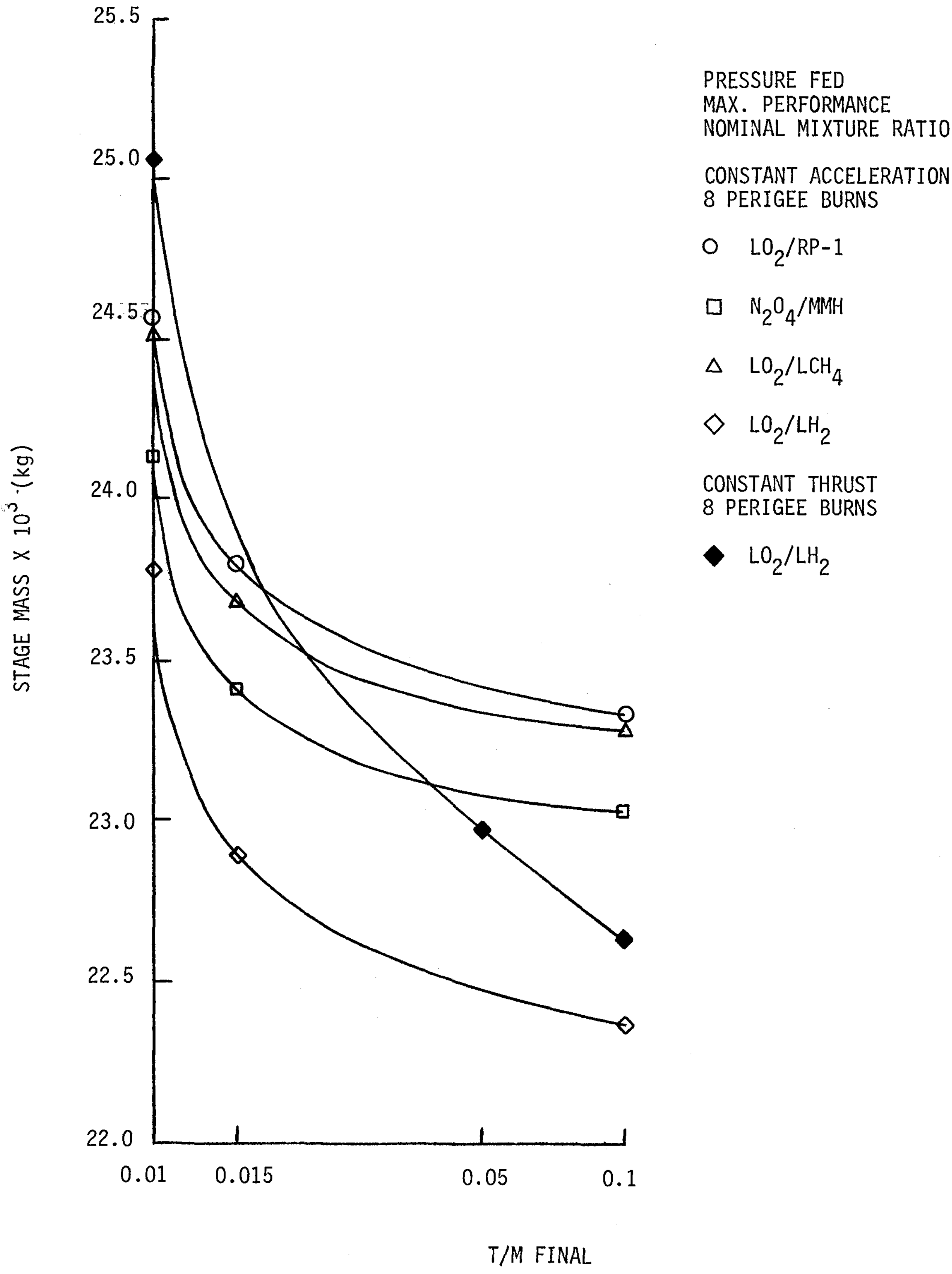


FIGURE V-6 STAGE MASS VERSUS THRUST-TO-MASS

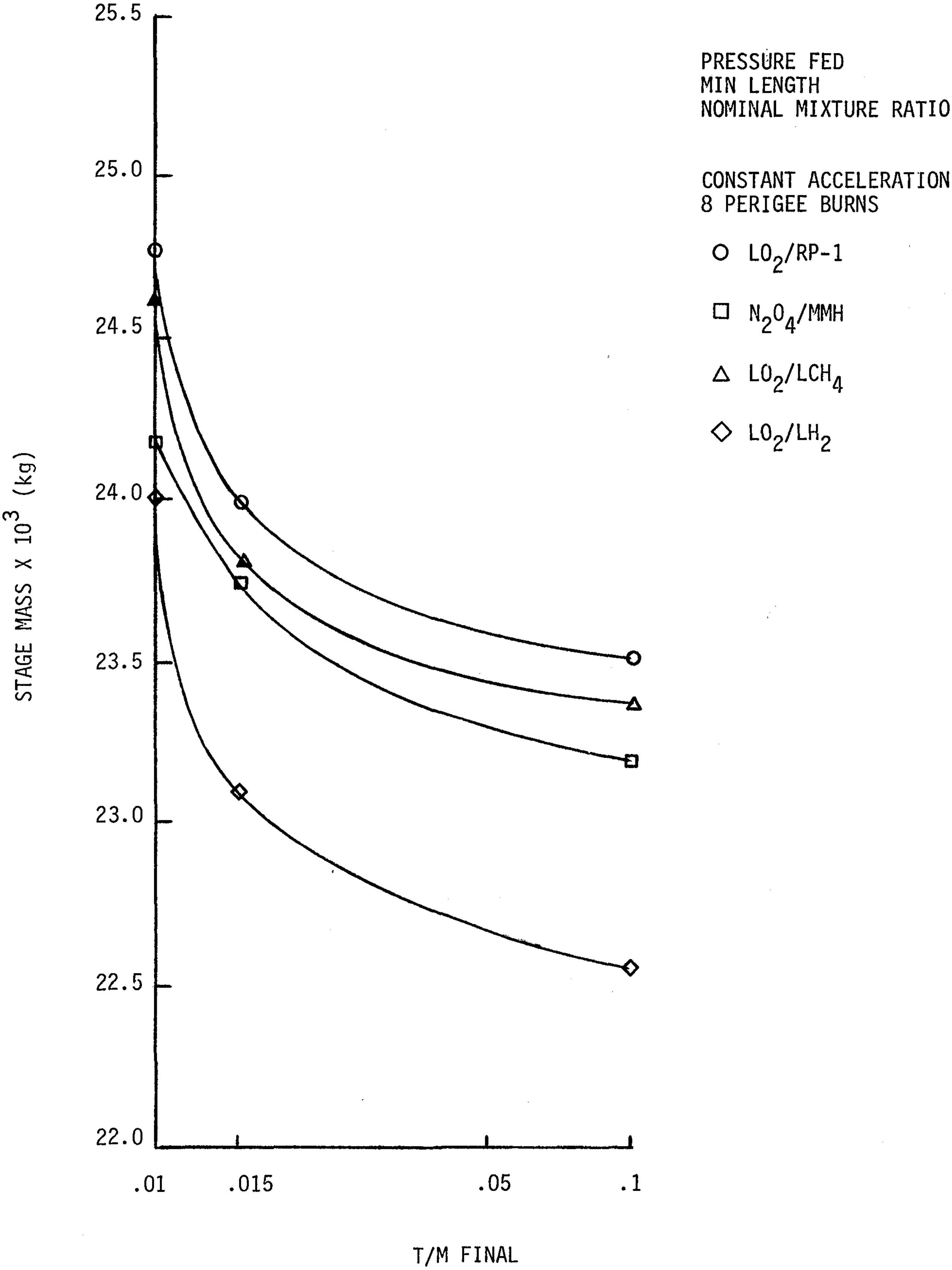


FIGURE V-7 - STAGE MASS VERSUS THRUST-TO-MASS

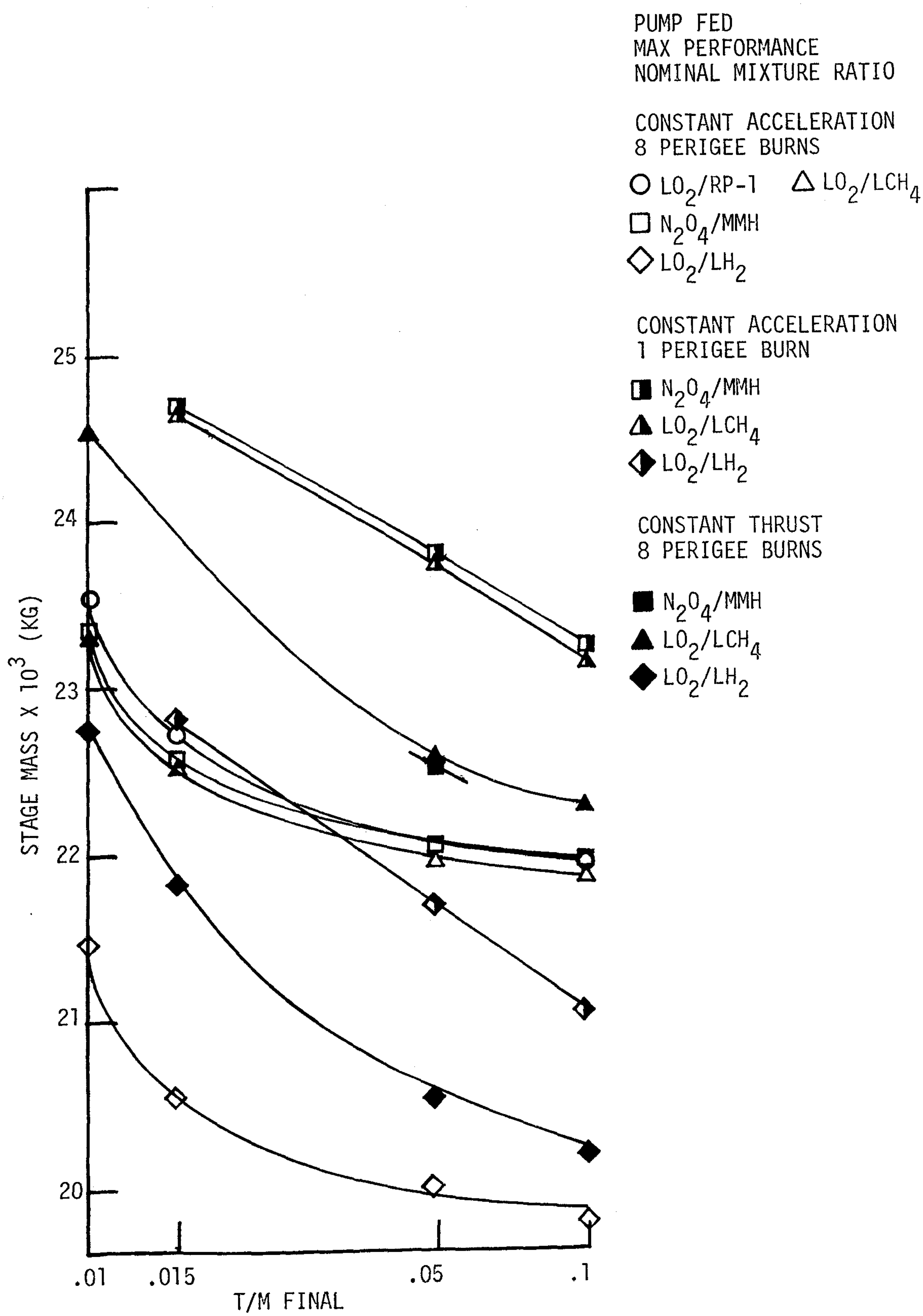


FIGURE V-8 - STAGE MASS VERSUS THRUST-TO- MASS

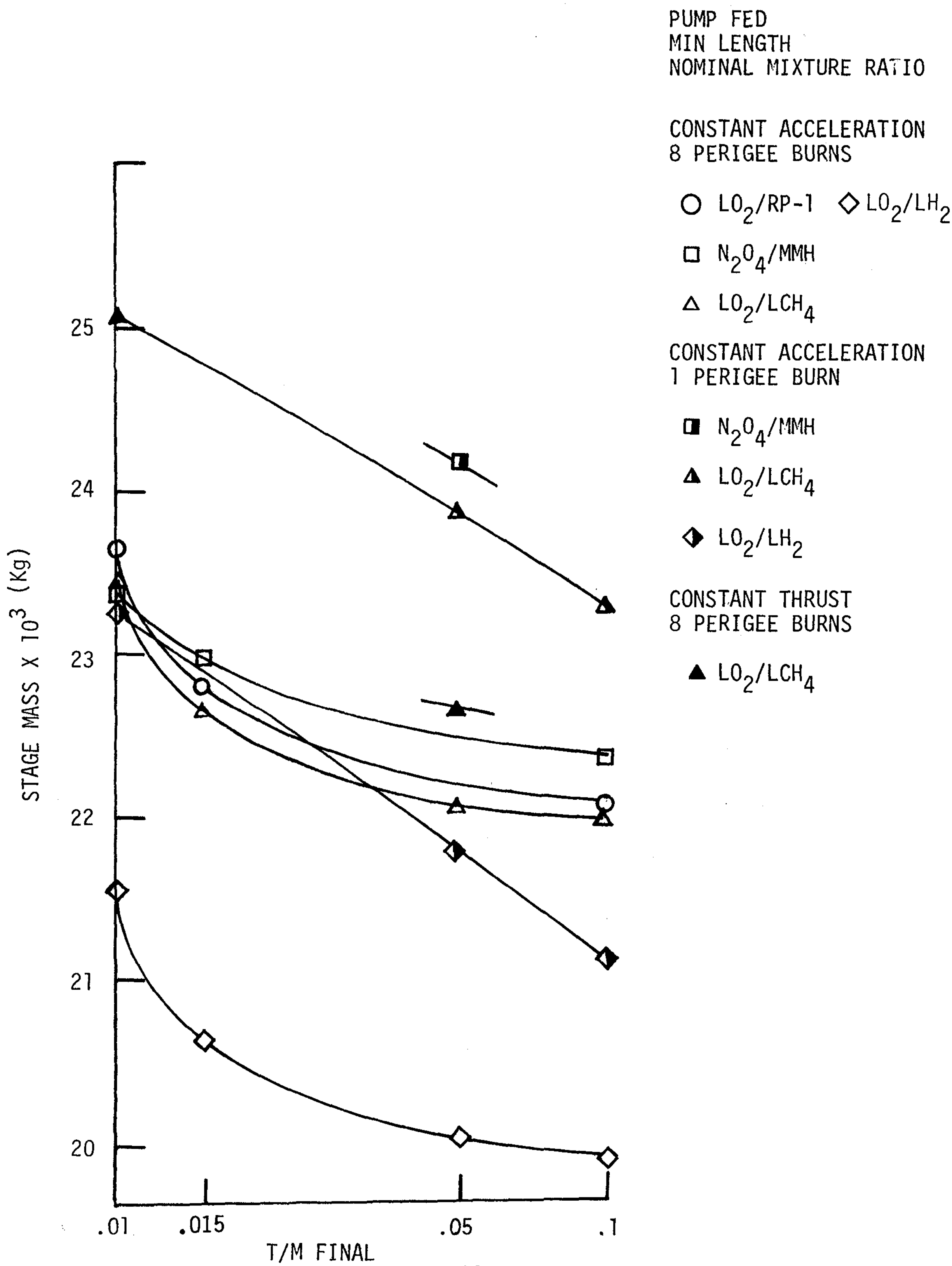


FIGURE V-9 - MASS FRACTION VERSUS THRUST-TO-MASS

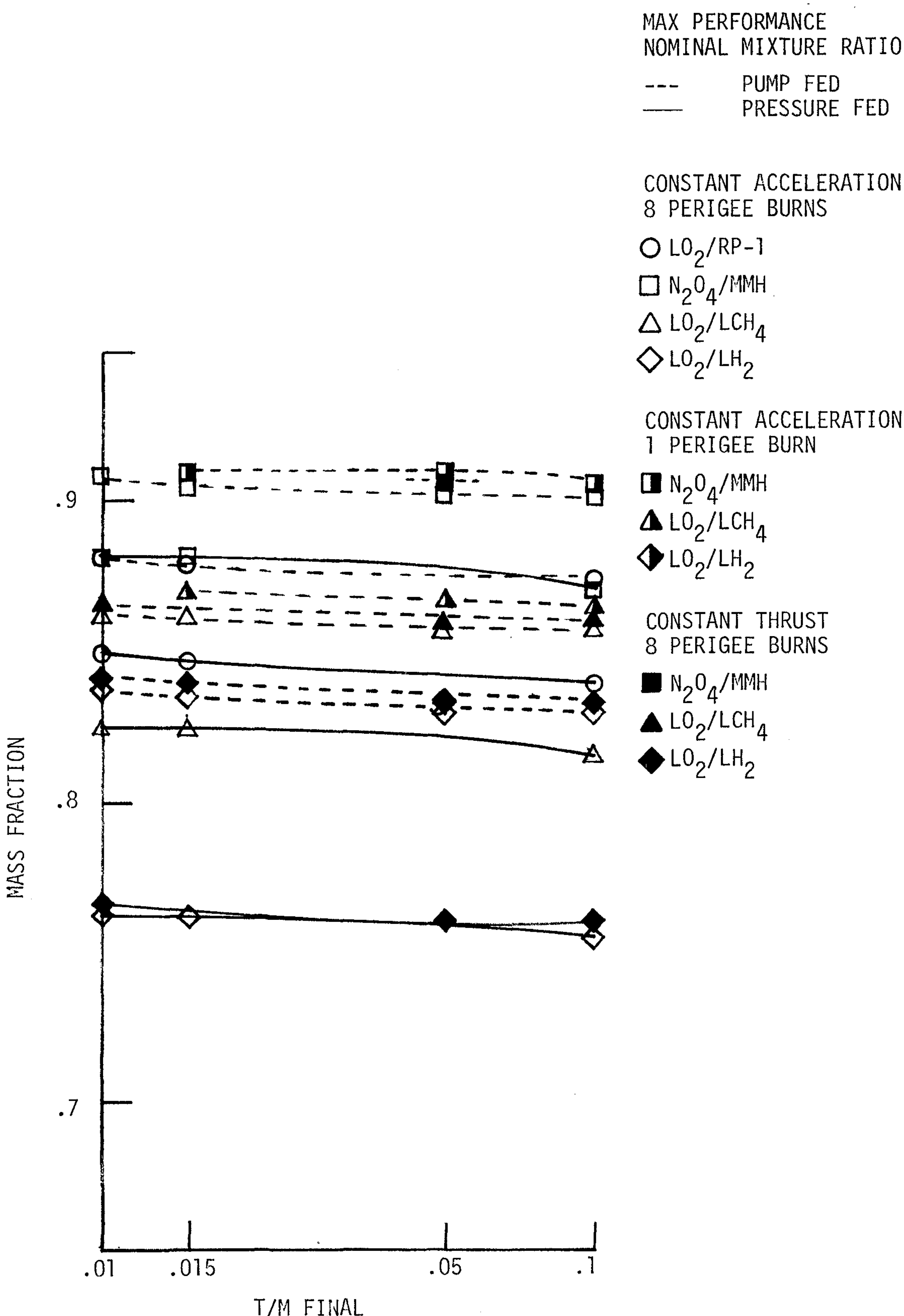


FIGURE V-10 - MASS FRACTION VERSUS THRUST-TO-MASS

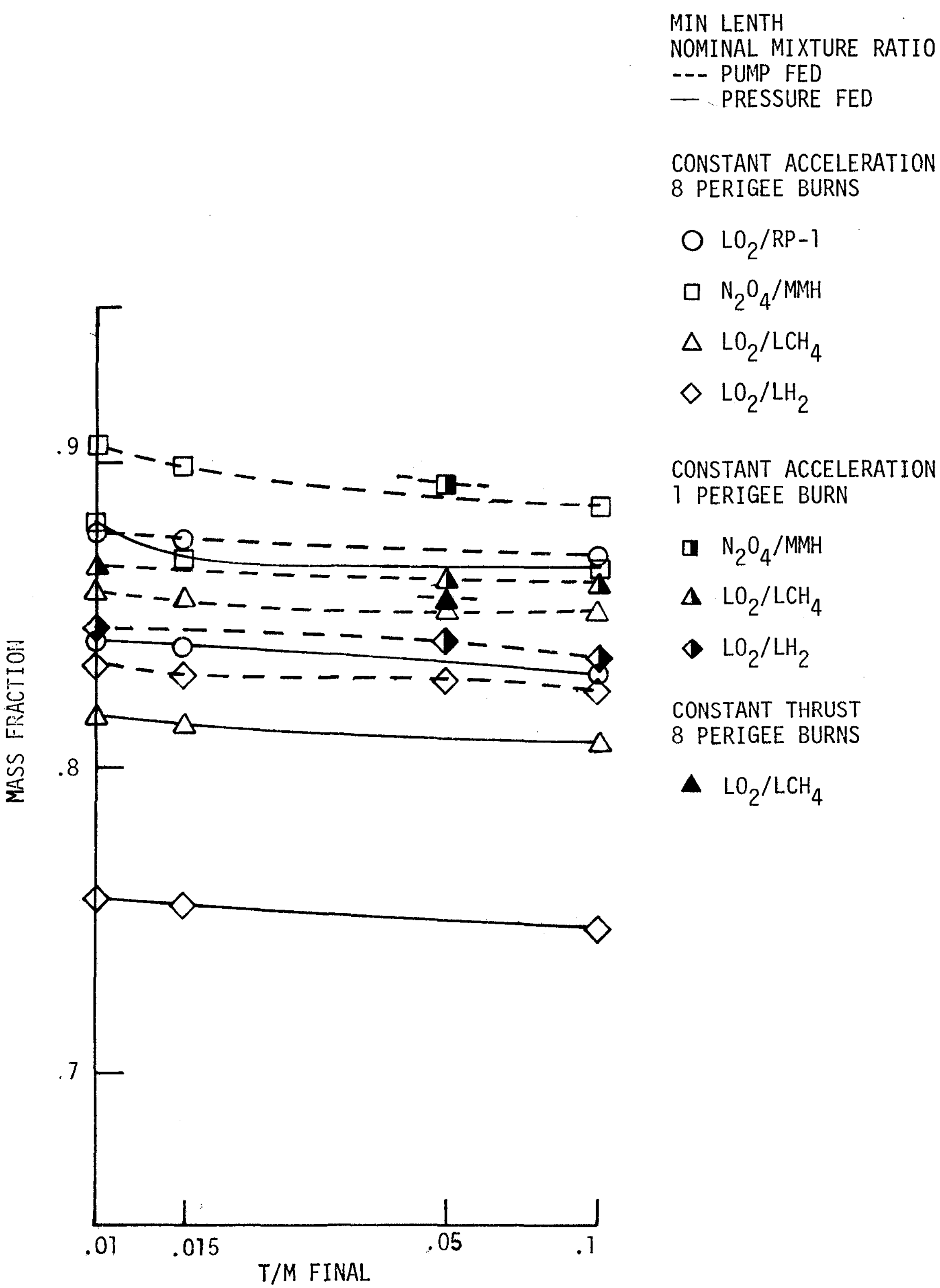


FIGURE V-11 - STAGE LENGTH VERSUS THRUST-TO-MASS

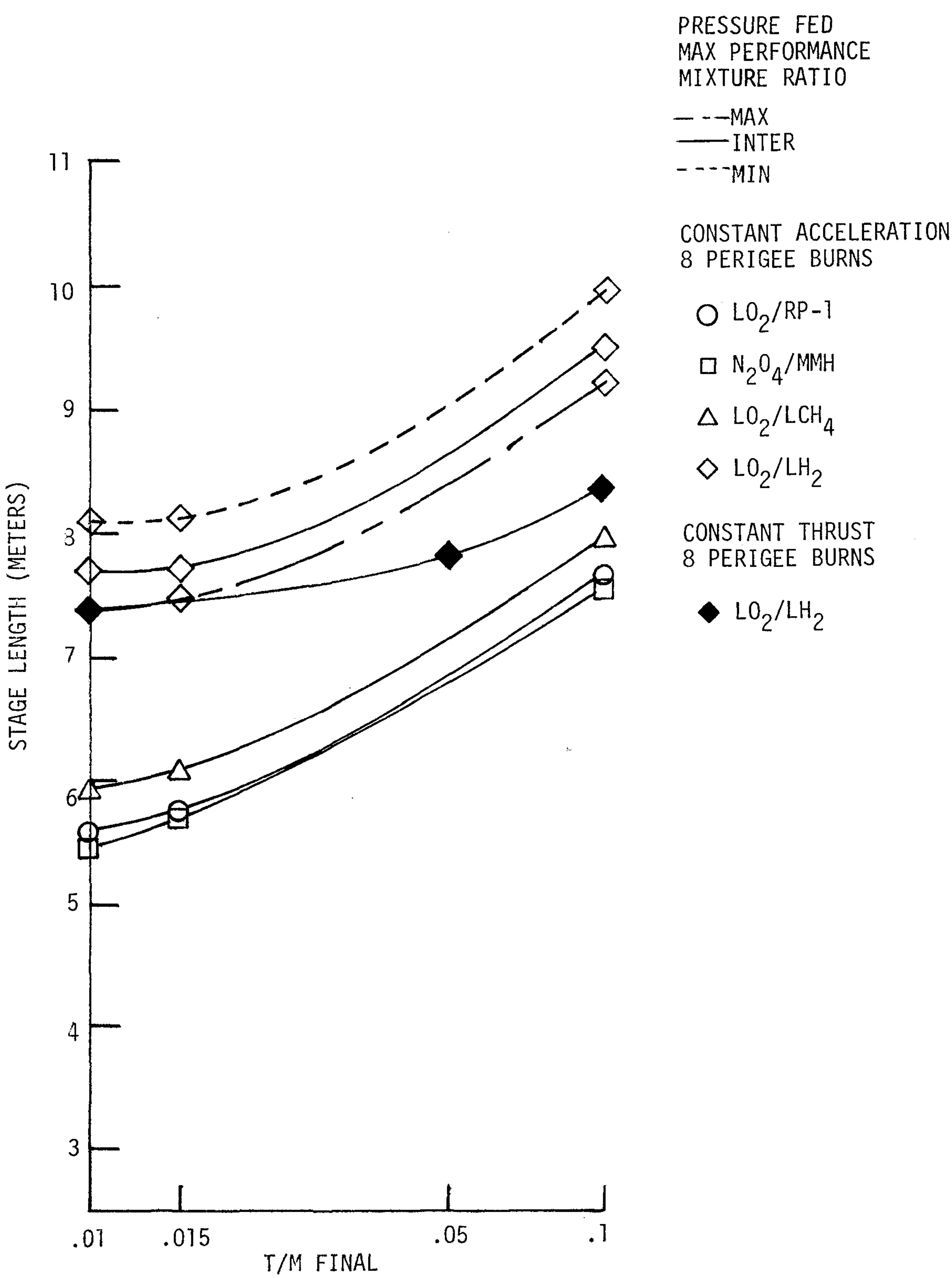


FIGURE V-12 - STAGE LENGTH VERSUS THRUST-TO-MASS

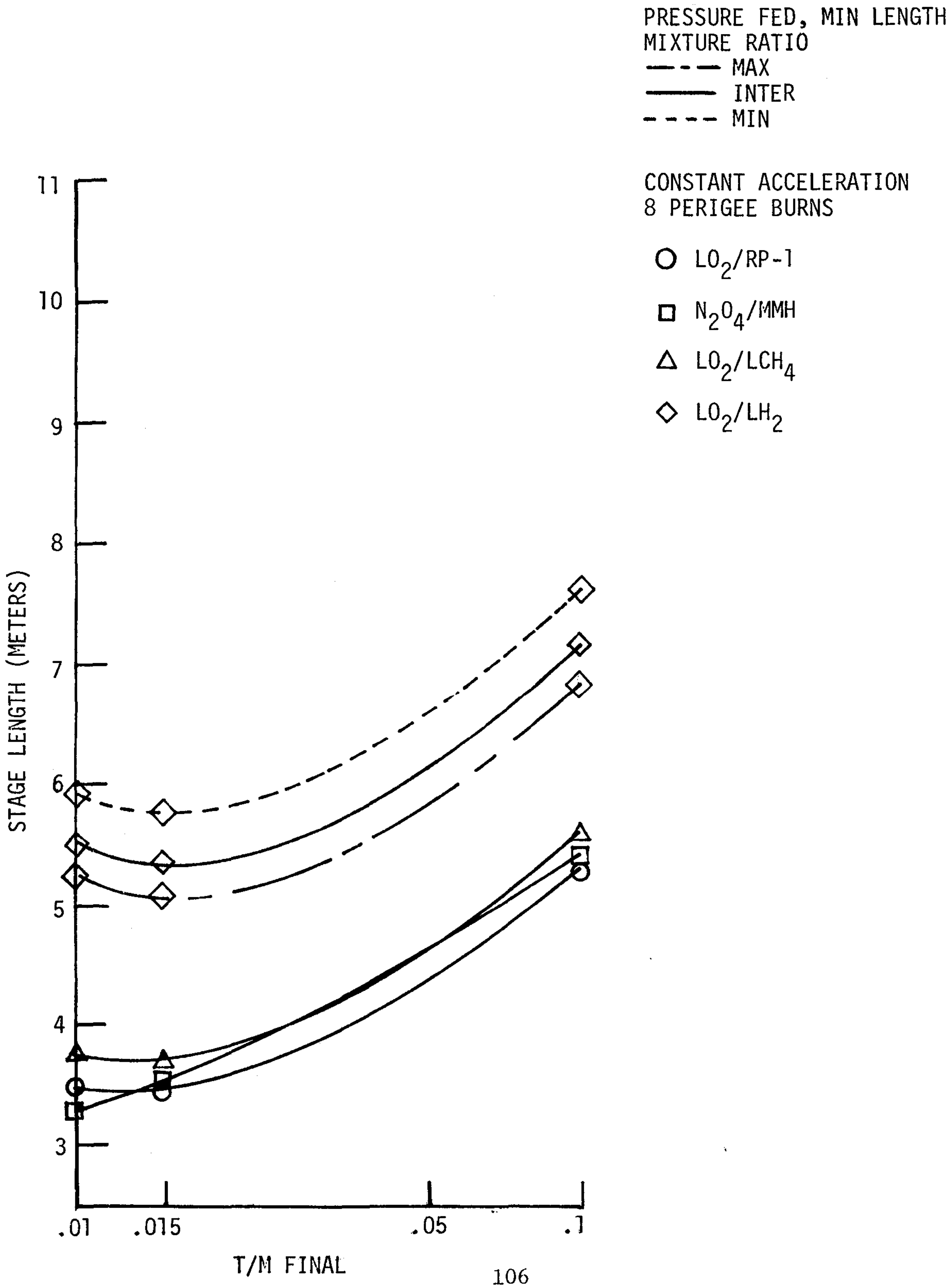


FIGURE V-13 STAGE LENGTH VERSUS THRUST-TO-MASS

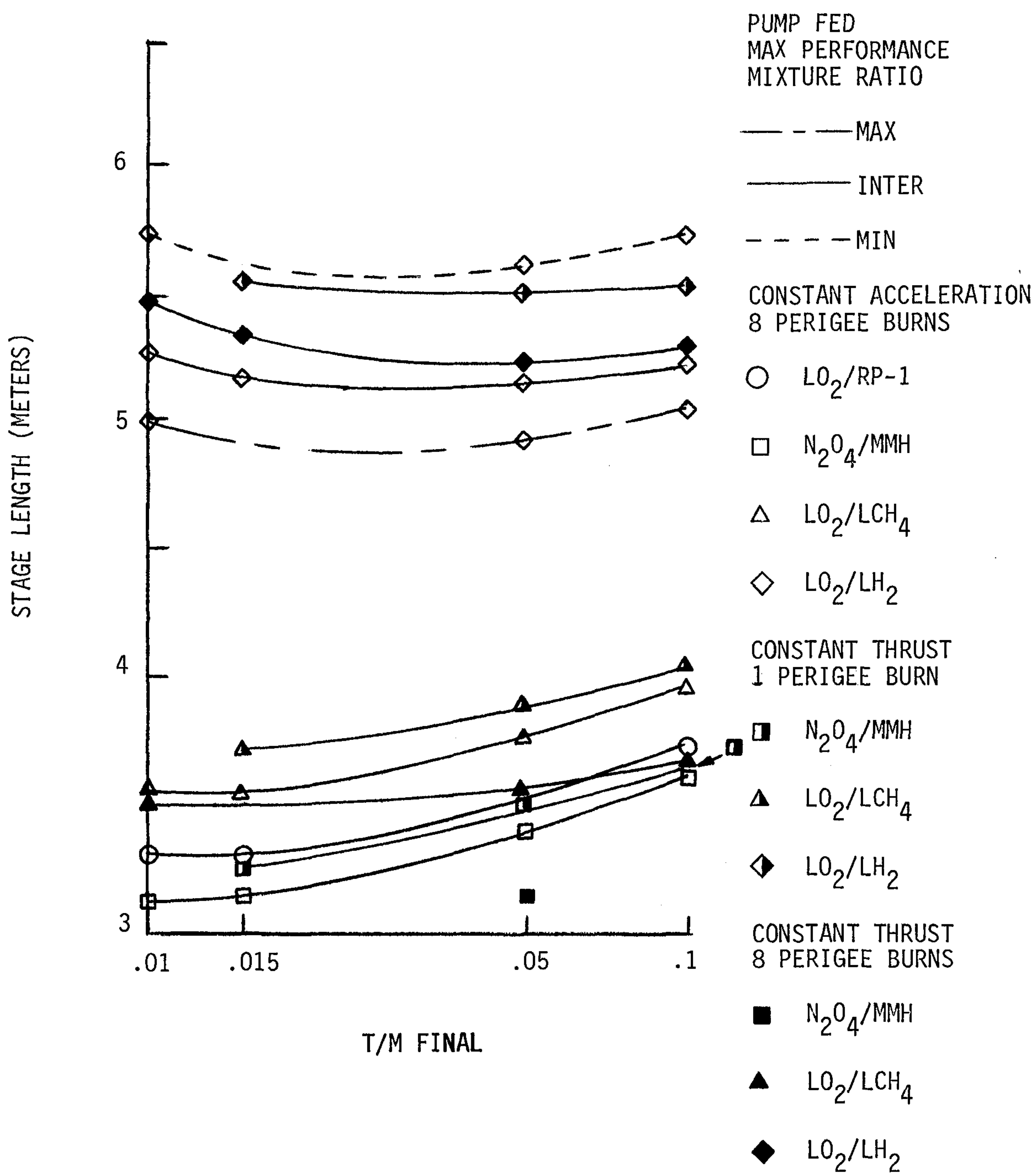
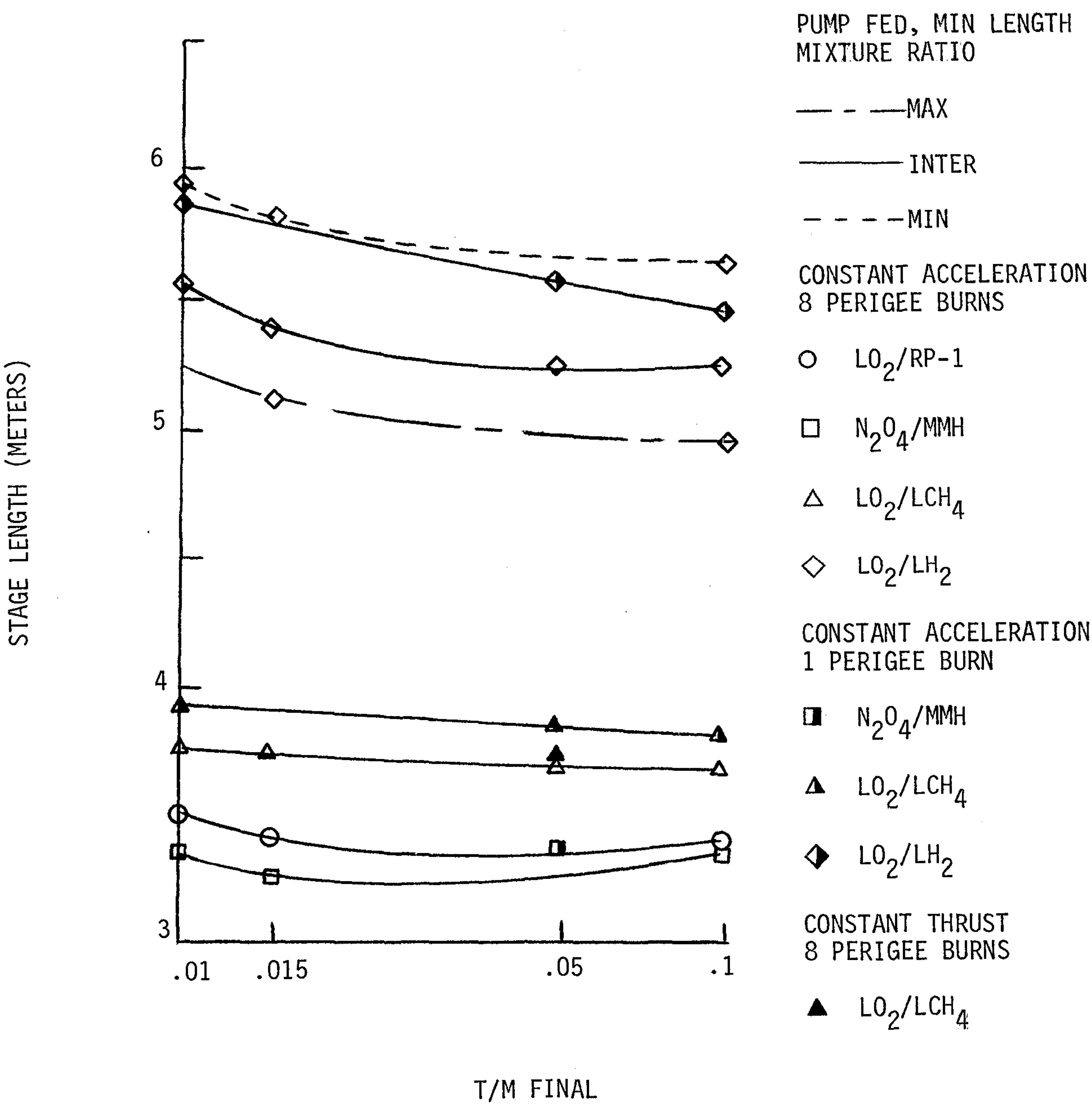


FIGURE V-14 STAGE LENGTH VERSUS THRUST-TO-MASS



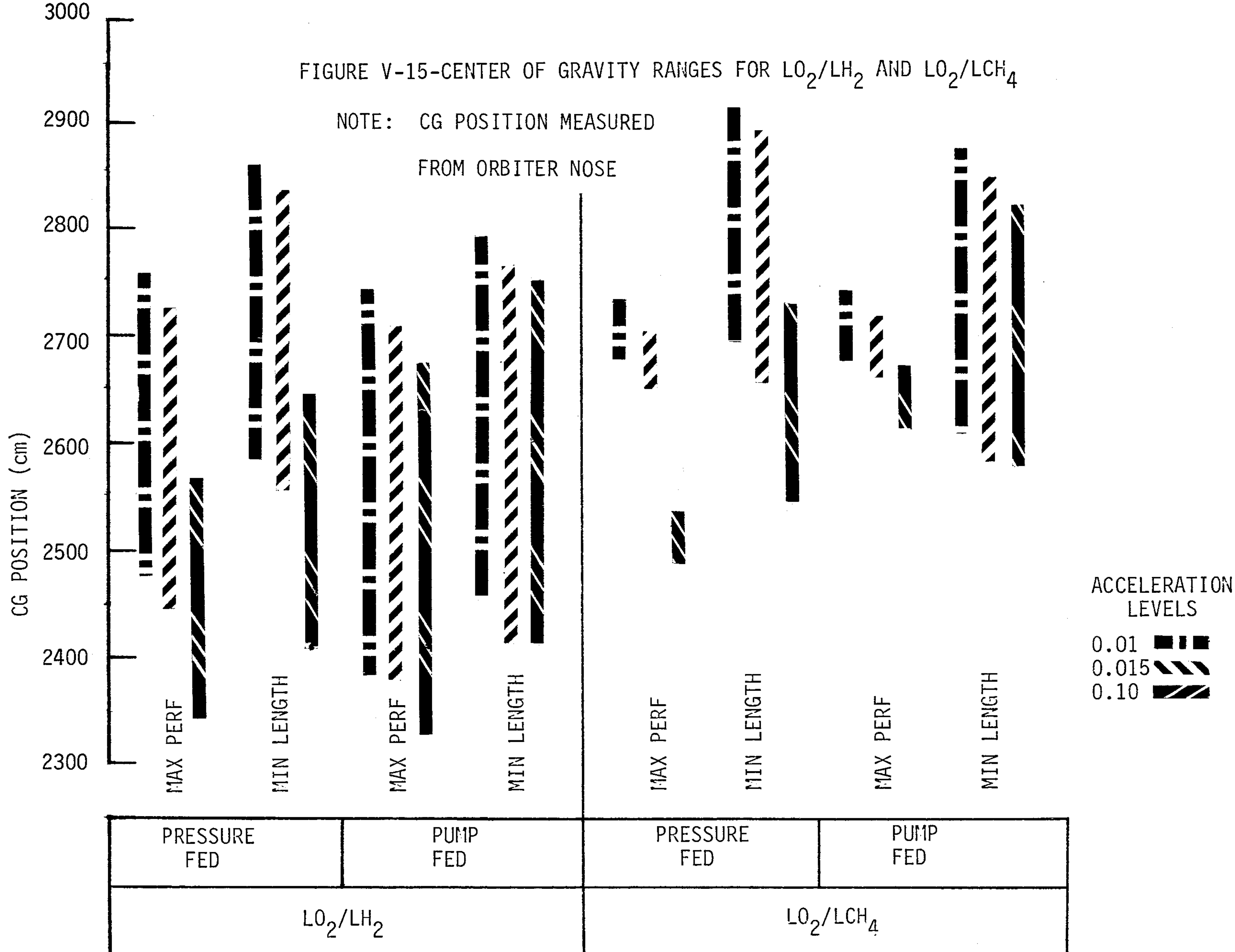


FIGURE V-15-CENTER OF GRAVITY RANGES FOR LO_2/LH_2 AND LO_2/LCH_4

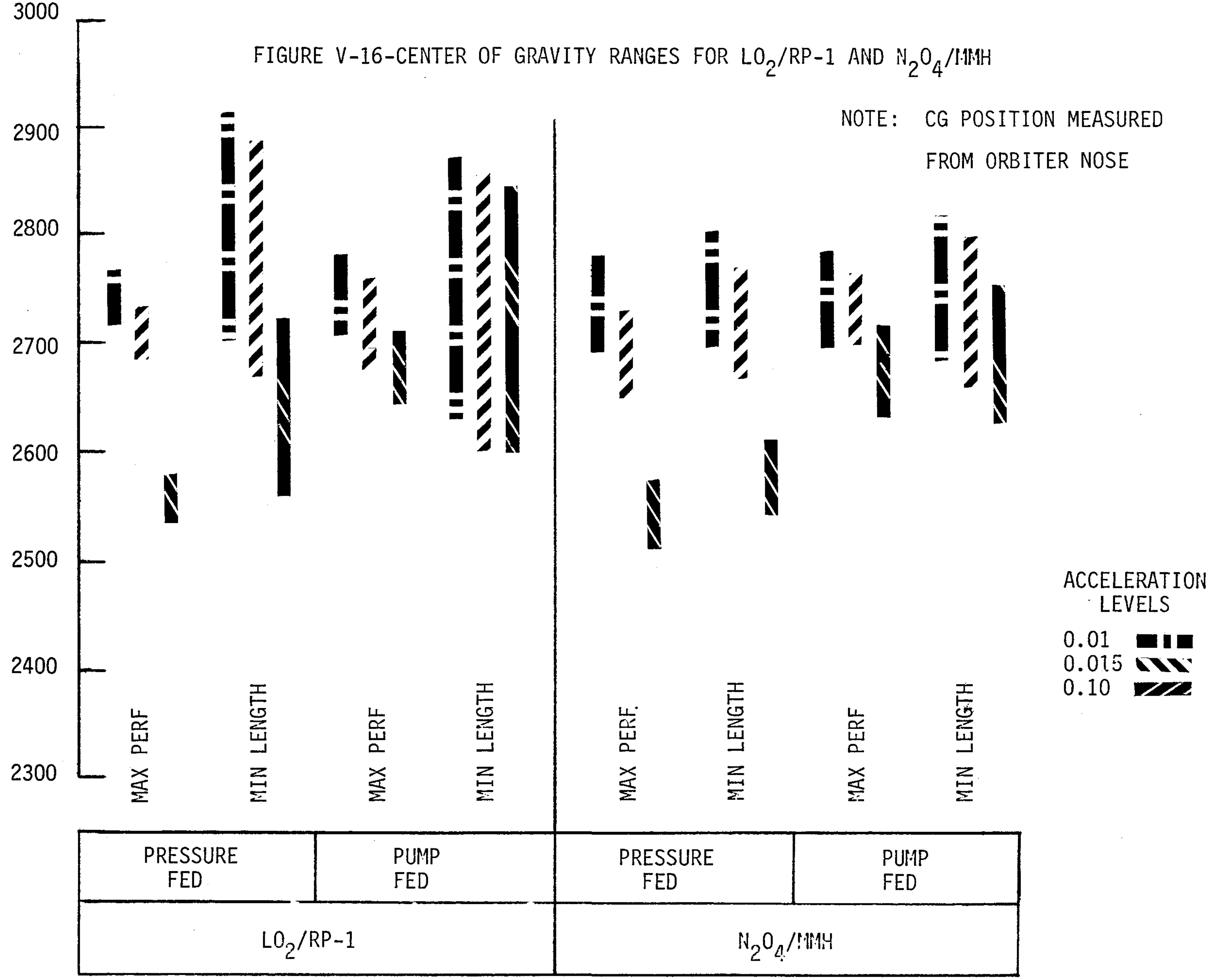


FIGURE V-16-CENTER OF GRAVITY RANGES FOR LO_2/RP-1 AND N_2O_4/MMH

nominal mixture ratio. The variation of mass fraction and stage mass was less than 3% for LO_2/LH_2 also. However, stage length variation for LO_2/LH_2 was 11% for the mixture ratio range as indicated in Figure V-11 through V-14.

2. Constant Acceleration - Constant Thrust Comparison

To compare the constant acceleration transfer method with the constant thrust transfer method, certain system parameters are held constant while final thrust/mass ratio varies. The constant parameters consist of an 8 perigee burn orbit transfer strategy, maximum performance stage configuration, and nominal mixture ratio. Table V-6 shows the comparison of stage mass and stage length associated with various propellant combinations for the two transfer methods. These values of length and mass are typical and representative of their respective families.

The results from Table V-6 indicate the constant acceleration approach delivers 478 to 574 Kg more payload mass at 0.05 g and 278 to 422 Kg more payload mass at 0.1 g than the constant thrust approach. However, the constant thrust method is capable of greater payload length delivery of 2 to 78 cm at 0.5 g and 5 to 115 cm at 0.1 g.

The constant acceleration method, which implies a throttling engine, requires less propellant due to reduced delta velocity requirements compared to the constant thrust method. This decrease in propellant mass yields higher payload mass. However, the payload length increase is primarily driven by engine length, and the constant thrust approach has a lower initial thrust level of the two transfer methods, resulting in a shorter engine length. Therefore, available payload length is greater for constant thrust than constant acceleration, for a fixed final thrust/mass ratio. The payload length increase (i.e engine length effect) is more pronounced for pressure-fed systems than pressure-fed systems since chamber and nozzle sizes for pressure-fed engines are larger.

The conclusions drawn from Table V-6 depend upon whether the payload is mass or length constrained. If increased payload mass is the primary consideration, a constant acceleration approach is suggested. Conversely, if payload length is more critical than mass, a constant thrust transfer method is preferred.

3. 1 Burn - 8 Burn Comparison (Perigee)

Table V-7 displays the contrast of stage mass and stage length between a 1 perigee burn and an 8 perigee burn orbit transfer strategy with final thrust/mass ratio as a parameter. Other system parameters, such as constant acceleration, pump-fed engines, and nominal mixture ratio, are set for this comparison. The propellant combinations and stage configuration are representative samples.

TABLE V-6 - CONSTANT THRUST VERSUS CONSTANT ACCELERATION COMPARISON (EIGHT PERIGEE BURN, MAXIMUM PERFORMANCE)

THRUST MASS	0.05 g		0.1 g	
	CONSTANT THRUST	CONSTANT ACCELERATION	CONSTANT THRUST	CONSTANT ACCELERATION
Pump Fed				
N_2O_4/MMH				
Stage Mass (Kg)	22570	22090	NA	22010
Stage Length (cm)	508	530	NA	551
LO_2/LH_2				
Stage Mass (Kg)	20550	20020	20240	19840
Stage Length (cm)	709	711	716	721
LO_2/LCH_4				
Stage Mass (Kg)	22580	22000	22320	21900
Stage Length (cm)	548	566	559	584
Pressure Fed				
LO_2/LH_2				
Stage Mass (Kg)	22960	22410*	22620	22340
Stage Length (cm)	785	863**	838	953

* THIS DATA POINT DERIVED BY INTERPOLATION FROM FIGURE V-5
** THIS DATA POINT DERIVED BY INTERPOLATION FROM FIGURE V-11

In all cases considered, the 8 burn strategy provides a minimum increase in payload mass of 1220 Kg and a minimum increase in available payload length of 8 cm over the respective values of the 1 burn strategy.

4. Pressure Fed - Pump Fed Comparison

Table V-8 presents data obtained from a constant acceleration, 8 perigee burn orbit transfer strategy with maximum performance stage configuration and nominal mixture ratio for all propellant combinations. The values in Table V- 8 display stage mass and stage length at a thrust/mass ratio of 0.1 g. Each of the four propellant combinations compare the pressure-fed systems parameters with pump-fed systems parameters.

TABLE V-7 - 1 PERIGEE BURN - 8 PERIGEE BURNS COMPARISON
(CONSTANT ACCELERATION, PUMP-FED)

THRUST/MASS	0.05 g		0.1 g	
NUMBER OF BURNS	1	8	1	8
N_2O_4/MMH				
Maximum Performance				
Stage Mass (Kg)	23840	22090	23270	22010
Stage Length (cm)	544	531	559	511
Minimum Length				
Stage Mass (Kg)	24220	22500*	N/A	22390
Stage Length (cm)	338	330**	N/A	335
LO_2/LCH_4				
Maximum Performance				
Stage Mass (Kg)	23785	22000	23210	21900
Stage Length (cm)	579	566	594	584
Minimum Length				
Stage Mass (Kg)	23900	22140	23310	22030
Stage Length (cm)	386	371	381	368
LO_2/LH_2				
Maximum Performance				
Stage Mass (Kg)	21710	20020	21080	19840
Stage Length (cm)	741	711	742	721
Minimum Length				
Stage Mass (Kg)	21810	20060	21160	19940
Stage Length (cm)	554	523	541	521

* DERIVED BY INTERPOLATION FROM FIGURE V-8
** DERIVED BY INTERPOLATION FROM FIGURE V-14

TABLE V-8 - PRESSURE FED AND PUMP FED MASS/LENGTH COMPARISONS FOR 0.1 g
(CONSTANT ACCELERATION, EIGHT PERIGEE BURNS)

PROPELLANT COMBINATION	PRESSURE-FED	PUMP-FED
N_2O_4/MMH		
Stage Mass (Kg)	23020	22010
Stage Length (cm)	757	511
LO_2/RP-1		
Stage Mass (Kg)	23320	22000
Stage Length (cm)	770	561
LO_2/LH_2		
Stage Mass (Kg)	22340	19840
Stage Length (cm)	953	721
LO_2/LCH_4		
Stage Mass (Kg)	23280	21900
Stage Length (cm)	800	584

As shown in Table V-8, when pump-fed systems are utilized, a minimum additional 1010 Kg of payload mass and 209 cm of payload length are available.

The pressure-fed systems are mass-penalized for the engine mass and tank mass which are linked to their higher operating pressures. The 178 cm stage length penalty is primarily due to the engine length, even in the minimum length stage configuration. Similar payload parameter results are found upon inspection of the minimum length configuration. However, the positive point for pressure-fed systems is that they eliminate the complex, expensive rotating machinery characteristic of pump-fed systems. The conclusion of this comparison is that pump-fed engines are preferred from the total systems viewpoint.

From the previous discussion, the 8 perigee burn, constant acceleration, pump-fed parametric data is the suggested stage configuration selected as the baseline to develop the relative merit of the various concepts.

VI. PROPULSION SYSTEMS COMPARISONS

A. Approach

Propulsion system comparisons were performed to provide insight as to how the primary propulsion system charactersistics, orbit transfer techniques, LSS mass and area, Shuttle cargo bay packaging, and engine technology are interactive. The relative merit of the various primary propulsion system characteristics was established by consideration of two factors - deliverable LSS mass and area.

A method, shown in Figure VI-1, was necessary to compare the various propellant combinations and tankage configurations with the Large Space Systems. This method incorporated available payload mass or available volume in the cargo bay, as a driver, in such a manner as to result in the maximum LSS diameter deliverable to GEO. The established procedure was to maximize the LSS diameter by utilizing 100% of either available payload mass or available payload volume without exceeding the other. The procedure begins with determining the diameter of a specific LSS class with a selected surface density by entering the appropriate system mass versus diameter curve (Figure III-7, III-16, and III-23) at a mass value equal to available payload mass. This yields a maximum deployed LSS diameter based on available payload mass.

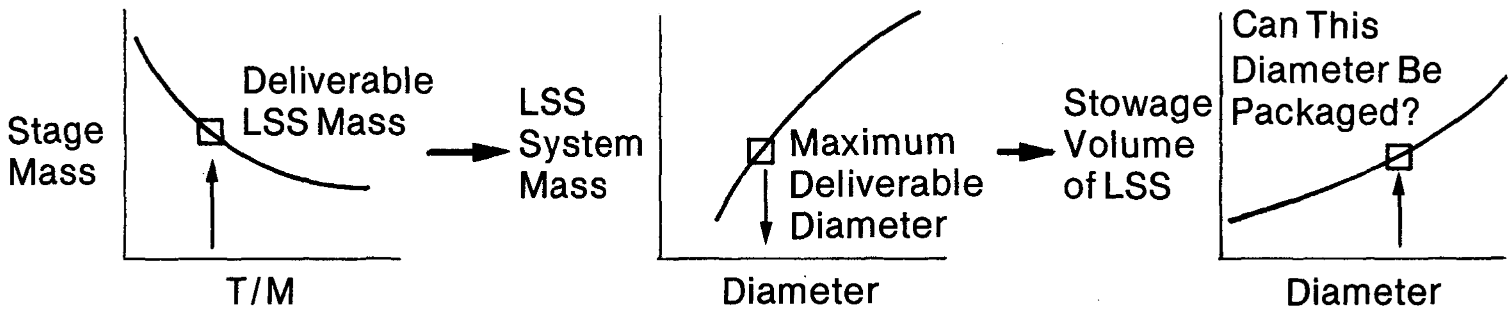
The question arises as to whether or not the packaged "maximum" LSS diameter exceeds the available payload volume. To answer this question a LSS storage volume analysis was conducted from which the results are presented in Figure VI-2 as stowage volume versus diameter. The baseline for Figure VI-2 is for a T/M range of 0.05 to 0.10 g's with available payload volume based upon a 4.1 meter stowed payload diameter. There are some minor volume increases at 0.10 g with the higher surface densities and larger diameters, but the change is less than 10%, which is well within the accuracy of the data. Only one volume curve is required for the hoop and column since the surface is stowed within the ring and and does not impact the overall length and volume. These data should not be taken as exact, especially with respect to the wrap radial rib. All curves were generated utilizing the best data available and engineering judgement. Figure VI-2 is now used to extract the stowage volume of the LSS corresponding to the maximum diameter. If the stowage volume is less than the payload volume, then the LSS is mass constrained. However, if the stowage volume is greater than the available payload volume, the LSS is volume constrained. If this is the case, the problem is worked in reverse starting with the available payload volume and ending with system total mass. This technique permitted determination of maximum LSS diameter for a given T/M which was compatible with propulsion system performance.

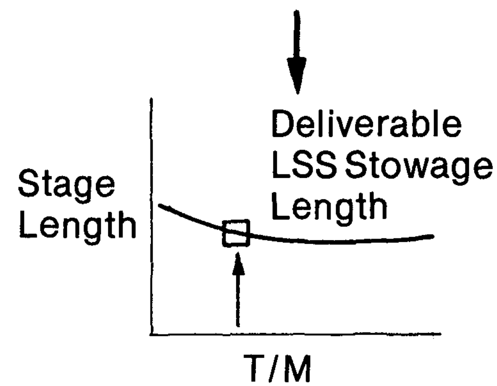
This procedure was followed for three transfer strategies (8 perigee burns, constant acceleration; 8 perigee burns, constant thrust; and 1 perigee burn, constant acceleration) with the eight possible combinations of LSS type and surface density as parameters.

Use 100% of Payload Mass or Volume

Select Propellant Combination, Tankage Configuration, Propellant Fed (Pump or Pressure), Orbit Transfer Strategy, Acceleration Level, LSS Class, and LSS Surface Density

Maximum LSS Diameter Not To Exceed 200 meters





— If diameter can be packaged, LSS is mass constrained.

— Diameter cannot be packaged, then proceed in reverse with maximum deliverable diameter to determine if mass-LSS is volume constrained.

FIGURE VI-1 INTERACTION METHODOLOGY

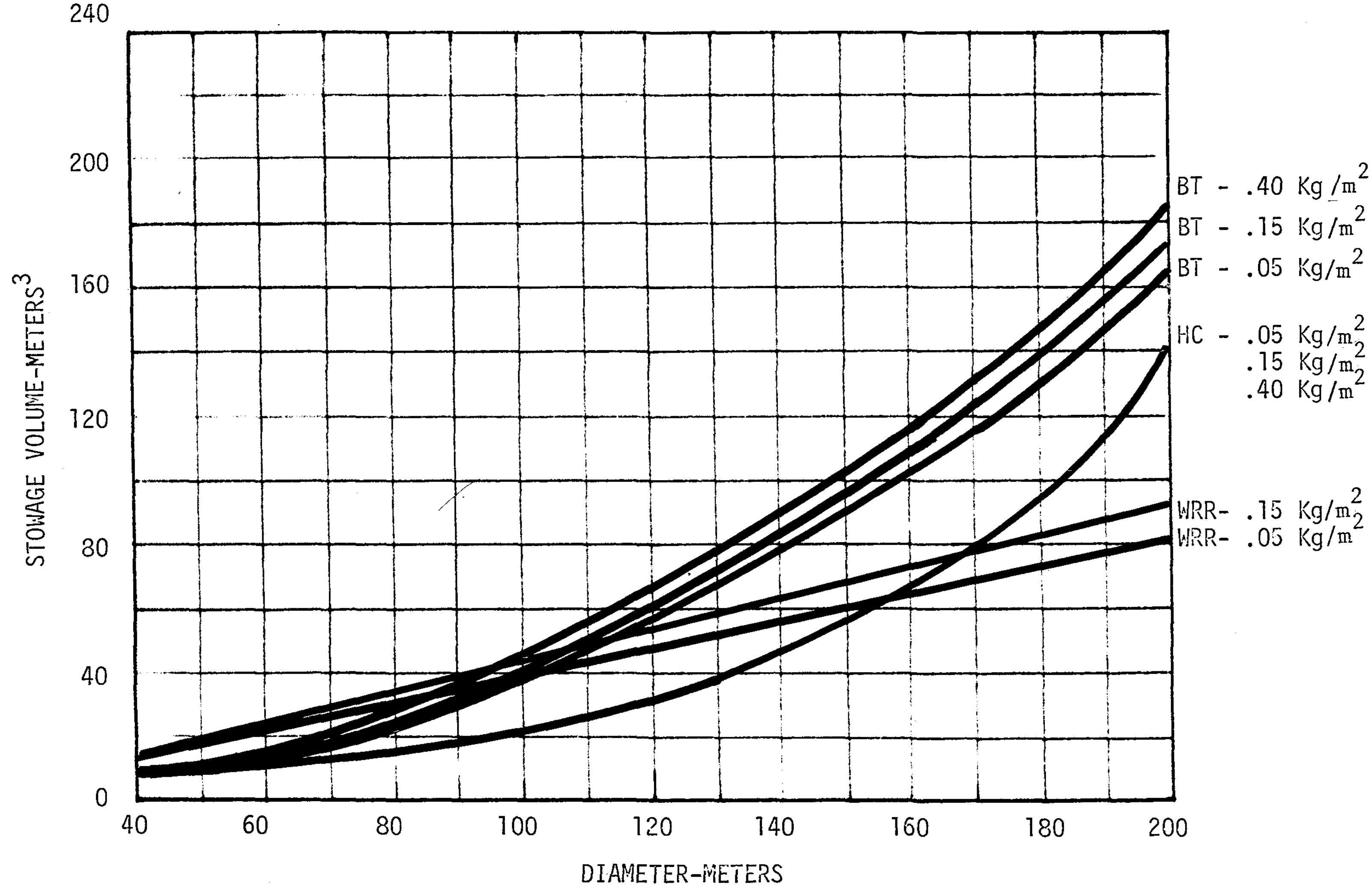


FIGURE VI-2-STOWAGE VOLUME FOR THE BOX TRUSS (BT), HOOP AND COLUMN (HC), AND WRAP RADIAL RIB (WRR) FOR 0.05-0.15-0.40 Kg/m^2 SURFACE DENSITY (T/M BETWEEN 0.05 AND 0.10 g's)

B. Results and Conclusions

There were a few situations where the available payoad mass and available payload volume exceeded the applicable range of the LSS data. In these cases, a maximum diameter, 200 meters, was chosen from the upper allowable limits of the payload.

Once the diameters have been tabulated, an equally weighted numerical average of the maximum diameters for each propellant combination and tankage configuration was calculated to determine propulsion system/LSS interaction trends. An average maximum diameter was used since future LSS characterisitics, i.e., structure class and surface density, have yet to be defined.

Table VI-1 correlates the interaction data with the table number for each interaction combination considered. Table VI-2 through Table VI-11 present the maximum LSS diameter in relation to tankage configuration and propellant combination.

TABLE VI - 1 - INTERACTION DATA CORRELATION

		g LEVEL	LO_2/RP-1	N_2O_4/MMH	LO_2/LCH_4	LO_2/LH_2
8 PERIGEE BURNS	CONSTANT ACCELERATION	0.01	2*	2	3	3
		0.05	4	4	5	5
		0.10	8	8	9	9
	CONSTANT THRUST	0.05	--	7	7	7
		0.10	--	--	11	11
1 PERIGEE BURN	CONSTANT ACCELERATION	0.05	--	6	6	6
		0.10	--	10	10	10

* INDICATES TABLE NUMBER

TABLE VI-2 MAXIMUM LSS DIAMETERS (METERS)

T/M = 0.01 g 8 PERIGEE BURNS PUMP FED
CONSTANT ACCELERATION NOMINAL MIXTURE RATIO

PROPULSION CONFIGURATION / LSS CONFIGURATION	LO_2/RP-1 MAX. PERF. $\left(\frac{x}{y}\right)$	LO_2/RP-1 MIN. LENGTH $\left(\frac{x}{y}\right)$	N_2O_4/MMH MAX. PERF. $\left(\frac{x}{y}\right)$	N_2O_4/MMH MIN. LENGTH $\left(\frac{x}{y}\right)$
BOX TRUSS				
0.05 kg/m^2	144 $\left(\frac{82}{139}\right)$	142 $\left(\frac{66}{146}\right)$	148 $\left(\frac{52}{138}\right)$	147 $\left(\frac{62}{148}\right)$
0.15 kg/m^2	124 $\left(\frac{75}{139}\right)$	122 $\left(\frac{84}{146}\right)$	128 $\left(\frac{69}{138}\right)$	127 $\left(\frac{80}{148}\right)$
0.40 kg/m^2	92 $\left(\frac{101}{139}\right)$	90 $\left(\frac{109}{146}\right)$	94 $\left(\frac{98}{138}\right)$	93 $\left(\frac{109}{148}\right)$
HOOP AND COLUMN				
0.05 kg/m^2	199* $\left(\frac{404}{3654}\right)$***	200**	199* $\left(\frac{712}{3862}\right)$***	200**
0.15 kg/m^2	157 $\left(\frac{75}{139}\right)$	155 $\left(\frac{83}{146}\right)$	161 $\left(\frac{70}{138}\right)$	160 $\left(\frac{81}{148}\right)$
0.40 kg/m^2	99 $\left(\frac{118}{139}\right)$	98 $\left(\frac{125}{146}\right)$	104 $\left(\frac{115}{138}\right)$	103 $\left(\frac{125}{148}\right)$
WRAP RADIAL RIB				
0.05 kg/m^2	89 $\left(\frac{105}{139}\right)$	88 $\left(\frac{112}{146}\right)$	92 $\left(\frac{102}{138}\right)$	91 $\left(\frac{113}{148}\right)$
0.15 kg/m^2	81 $\left(\frac{104}{139}\right)$	80 $\left(\frac{112}{146}\right)$	84 $\left(\frac{102}{138}\right)$	83 $\left(\frac{113}{148}\right)$
AVERAGE	123	122	126	126

* VOLUME CONSTRAINED, OTHERWISE MASS CONSTRAINED.

** THESE DIAMETERS ARE NOT BASED ON MAXIMIZED PAYLOAD VOLUME OR PAYLOAD MASS DUE TO LIMITATIONS IMPOSED UPON LSS DATA.

*** MASS RATIO - ALL OTHERS ARE DIAMETER (VOLUME) RATIOS.

$\left(\frac{x}{y}\right)$ X IS THE REMAINING VOLUME (M^3) OR MASS (kg) NOT OCCUPIED BY THIS LSS,
Y IS THE AVAILABLE PAYLOAD VOLUME OR AVAILABLE PAYLOAD MASS.

TABLE VI-3 MAXIMUM LSS DIAMETERS (METERS)

T/M = 0.01 g 8 PERIGEE BURN PUMP FED
CONSTANT ACCELERATION NOMINAL MIXTURE RATIO

PROPULSION CONFIGURATION / LSS CONFIGURATION	LO_2/LCH_4 MAX. PERF. $(\frac{x}{y})$	LO_2/LCH_4 MIN. LENGTH $(\frac{x}{y})$	LO_2/LH_2 MAX. PERF. $(\frac{x}{y})$	LO_2/LH_2 MIN. LENGTH $(\frac{x}{y})$
BOX TRUSS				
0.05 kg/m^2	149 $(\frac{45}{133})$	146 $(\frac{58}{142})$	165* $(\frac{818}{5718})$***	172* $(\frac{335}{5635})$***
0.15 kg/m^2	127 $(\frac{65}{133})$	125 $(\frac{77}{142})$	148 $(\frac{16}{109})$	146 $(\frac{28}{119})$
0.40 kg/m^2	93 $(\frac{94}{133})$	92 $(\frac{104}{142})$	113 $(\frac{49}{109})$	112 $(\frac{61}{119})$
HOOP AND COLUMN				
0.05 kg/m^2	198* $(\frac{720}{3870})$***	200**	188* $(\frac{2918}{5718})$***	192* $(\frac{2685}{5635})$***
0.15 kg/m^2	162 $(\frac{64}{133})$	160 $(\frac{75}{142})$	188* $(\frac{318}{5718})$***	191 $(\frac{1}{119})$
0.40 kg/m^2	104 $(\frac{110}{133})$	103 $(\frac{119}{142})$	130 $(\frac{86}{109})$	129 $(\frac{82}{119})$
WRAP RADIAL RIB				
0.05 kg/m^2	92 $(\frac{98}{133})$	91 $(\frac{107}{142})$	116 $(\frac{64}{109})$	112 $(\frac{75}{119})$
0.15 kg/m^2	84 $(\frac{97}{133})$	82 $(\frac{107}{142})$	102 $(\frac{64}{109})$	100 $(\frac{75}{119})$
AVERAGE	126	125	144	144

* VOLUME CONSTRAINED, OTHERWISE MASS CONSTRAINED.

** THESE DIAMETERS ARE NOT BASED ON MAXIMIZED PAYLOAD VOLUME OR PAYLOAD MASS DUE TO LIMITATIONS IMPOSED UPON LSS DATA.

*** MASS RATIO - ALL OTHERS ARE DIAMETER (VOLUME) RATIOS.

$(\frac{x}{y})$ X IS THE REMAININT VOLUME (M^3) OR MASS (kg) NOT OCCUPIED BY THIS LSS,
Y IS THE AVAILABLE PAYLOAD VOLUME OR AVAILABLE PAYLOAD MASS.

TABLE VI-4 MAXIMUM LSS DIAMETERS (METERS)

T/M = 0.05 g 8 PERIGEE BURN CONSTANT ACCELERATION

PUMP FED NOMINAL MIXTURE RATIO

LSS Configuration \ Propulsion Configuration	LO_2/RP-1				N_2O_4/MMH			
	MAX. PERF.	$(\frac{x}{y})$	MIN. LENGTH	$(\frac{x}{y})$	MAX. PERF.	$(\frac{x}{y})$	MIN. LENGTH	$(\frac{x}{y})$
BOX TRUSS								
0.05 Kg/M^2	162	$(\frac{35}{137})$	158	$(\frac{50}{150})$	162	$(\frac{34}{138})$	156	$(\frac{52}{148})$
0.15 Kg/M^2	138	$(\frac{55}{137})$	136	$(\frac{70}{150})$	138	$(\frac{56}{138})$	135	$(\frac{70}{148})$
0.40 Kg/M^2	106	$(\frac{85}{137})$	104	$(\frac{100}{150})$	105	$(\frac{86}{138})$	102	$(\frac{100}{148})$
HOOP/COLUMN								
0.05 Kg/M^2	198*	$(\frac{1728}{5100})$***	200**		199*	$(\frac{1730}{5130})$***	200**	
0.15 Kg/M^2	178	$(\frac{45}{137})$	176	$(\frac{60}{150})$	178	$(\frac{46}{138})$	172	$(\frac{66}{148})$
0.40 Kg/M^2	120	$(\frac{106}{137})$	118	$(\frac{120}{150})$	120	$(\frac{107}{138})$	115	$(\frac{120}{148})$
WRAP RADIAL RIB								
0.05 Kg/M^2	106	$(\frac{95}{137})$	105	$(\frac{109}{150})$	106	$(\frac{96}{138})$	102	$(\frac{108}{148})$
0.15 Kg/M^2	97	$(\frac{95}{137})$	96	$(\frac{108}{150})$	97	$(\frac{96}{138})$	93	$(\frac{108}{148})$
AVERAGE	138		137		138		135	

* VOLUME CONSTRAINED, OTHERWISE MASS CONSTRAINED.

** THESE DIAMETERS ARE NOT BASED ON MAXIMIZED PAYLOAD MASS DUE TO LIMITATIONS IMPOSED UPON LSS DATA.

*** MASS RATIO - ALL OTHERS ARE DIAMETER (VOLUME) RATIOS

$(\frac{x}{y})$ WHERE: X IS THE REMAINING VOLUME (M^3) or MASS (kg) NOT OCCUPIED BY THIS LSS, Y IS THE AVAILABLE PAYLOAD VOLUME OR AVAILABLE PAYLOAD MASS

TABLE VI-5 MAXIMUM LSS DIAMETERS (METERS)

T/M = 0.05 g 8 PERIGEE BURN CONSTANT ACCELERATION — PUMP FED NOMINAL MIXTURE RATIO

Propulsion Configuration / LSS Configuration	LO_2/LCH_4 MAX. PERF.	$(\frac{x}{y})$	LO_2/LCH_4 MIN. LENGTH	$(\frac{x}{y})$	LO_2/LH_2 MAX. PERF.	$(\frac{x}{y})$	LO_2/LH_2 MIN. LENGTH	$(\frac{x}{y})$
BOX TRUSS								
0.05 Kg/M^2	164	$(\frac{15}{131})$	164	$(\frac{29}{145})$	166*	$(\frac{1470}{7170})$***	172*	$(\frac{1360}{7160})$***
0.15 Kg/M^2	139	$(\frac{49}{131})$	138	$(\frac{63}{145})$	154	$(\frac{9}{111})$	154	$(\frac{24}{126})$
0.40 Kg/M^2	106	$(\frac{79}{131})$	105	$(\frac{93}{145})$	122	$(\frac{43}{111})$	121	$(\frac{59}{126})$
HOOP/COLUMN								
0.05 Kg/M^2	196*	$(\frac{1970}{5218})$***	200**		189*	$(\frac{4170}{7170})$***	195*	$(\frac{3910}{7160})$***
0.15 Kg/M^2	173	$(\frac{48}{131})$	172	$(\frac{63}{145})$	189*	$(\frac{1170}{7170})$***	195*	$(\frac{650}{7160})$***
0.40 Kg/M^2	121	$(\frac{99}{131})$	120	$(\frac{114}{145})$	142	$(\frac{64}{111})$	142	$(\frac{79}{126})$
WRAP RADIAL RIB								
0.05 Kg/M^2	107	$(\frac{89}{131})$	106	$(\frac{104}{145})$	124	$(\frac{62}{111})$	124	$(\frac{77}{126})$
0.15 Kg/M^2	96	$(\frac{89}{131})$	96	$(\frac{103}{145})$	115	$(\frac{60}{111})$	115	$(\frac{75}{126})$
AVERAGE	138		138		150		152	

* VOLUME CONSTRAINED, OTHERWISE MASS CONSTRAINED.

** THESE DIAMETERS ARE NOT BASED ON MAXIMIZED PAYLOAD VOLUME OR PAYLOAD MASS DUE TO LIMITATIONS IMPOSED UPON LSS DATA.

*** MASS RATIO - ALL OTHERS ARE DIAMETER (VOLUME) RATIOS

$(\frac{x}{y})$ X IS THE REMAINING VOLUME (M^3) OR MASS (kg) NOT OCCUPIED BY THIS LSS,
Y IS THE AVAILABLE PAYLOAD VOLUME OR AVAILABLE PAYLOAD MASS.

TABLE VI-6 MAXIMUM LSS DIAMETERS (METERS)

T/M = 0.05 g 1 PERIGEE BURN
CONSTANT ACCELERATION
PUMP FED
NOMINAL MIXTURE RATIO

LSS Configuration \ Propulsion Configuration	N_2O_4/MMH MAX. PERF.	$(\frac{x}{y})$	LO_2/LH_2 MAX. PERF.	$(\frac{x}{y})$	LO_2/LH_2 MIN. LENGTH	$(\frac{x}{y})$	LO_2/LCH_4 MAX. PERF.	$(\frac{x}{y})$	LO_2/LCH_4 MIN. LENGTH	$(\frac{x}{y})$
BOX TRUSS										
0.05 Kg/M^2	136	$(\frac{60}{136})$	164*	$(\frac{400}{5500})$***	167	$(\frac{21}{132})$	137	$(\frac{53}{130})$	136	$(\frac{65}{141})$
0.15 Kg/M^2	117	$(\frac{76}{136})$	142	$(\frac{20}{107})$	141	$(\frac{47}{132})$	118	$(\frac{69}{130})$	113	$(\frac{85}{141})$
0.40 Kg/M^2	85	$(\frac{105}{136})$	109	$(\frac{55}{107})$	108	$(\frac{81}{132})$	86	$(\frac{98}{130})$	84	$(\frac{111}{141})$
HOOP/COLUMN										
C.05 Kg/M^2	198*	$(\frac{30}{3380})$***	186*	$(\frac{2700}{5500})$***	197*	$(\frac{2100}{5400})$***	196*	$(\frac{180}{3400})$***	198	$(\frac{5}{141})$
0.15 Kg/M^2	148	$(\frac{84}{136})$	183	$(\frac{7}{107})$	182	$(\frac{34}{132})$	149	$(\frac{77}{130})$	147	$(\frac{90}{141})$
0.40 Kg/M^2	93	$(\frac{117}{136})$	124	$(\frac{73}{107})$	123	$(\frac{99}{132})$	95	$(\frac{110}{130})$	93	$(\frac{122}{141})$
WRAP RADIAL RIB										
0.05 Kg/M^2	86	$(\frac{103}{136})$	110	$(\frac{64}{107})$	109	$(\frac{89}{132})$	87	$(\frac{96}{130})$	85	$(\frac{108}{141})$
0.15 Kg/M^2	79	$(\frac{103}{136})$	100	$(\frac{63}{107})$	99	$(\frac{89}{132})$	79	$(\frac{97}{130})$	77	$(\frac{109}{141})$
AVERAGE	118		140		141		118		117	

* VOLUME CONSTRAINED, OTHERWISE MASS CONSTRAINED

*** MASS RATIO - ALL OTHERS ARE DIAMETER (VOLUME) RATIOS

$(\frac{x}{y})$ WHERE: X IS THE REMAINING VOLUME (M^3) OR MASS (kg) NOT OCCUPIED BY THIS LSS,
Y IS THE AVAILABLE PAYLOAD VOLUME OR AVAILABLE PAYLOAD MASS.

TABLE VI-7 MAXIMUM LSS DIAMETERS (METERS)

T/M = 0.05g 8 PERIGEE BURNS PUMP FED
CONSTANT THRUST NOMINAL MIXTURE RATIO

LSS Configuration \ Propulsion Config.	N_2O_4/MMH Max Perf.	$\left(\frac{x}{y}\right)$	LO_2/LH_2 Max Perf.	$\left(\frac{x}{y}\right)$	LO_2/LH_2 MIN Length	$\left(\frac{x}{y}\right)$	LO_2/LCH_4 Max Perf.	$\left(\frac{x}{y}\right)$	LO_2/LCH_4 Min Length	$\left(\frac{x}{y}\right)$
BOX TRUSS										
0.05 Kg/M^2	157	$\left(\frac{42}{141}\right)$	166*	$\left(\frac{1370}{6670}\right)$***	182	$\left(\frac{2}{134}\right)$	157	$\left(\frac{35}{134}\right)$	155	$\left(\frac{47}{133}\right)$
0.15 Kg/M^2	134	$\left(\frac{64}{141}\right)$	151	$\left(\frac{3}{110}\right)$	149	$\left(\frac{39}{134}\right)$	134	$\left(\frac{57}{134}\right)$	133	$\left(\frac{67}{143}\right)$
0.40 Kg/M^2	101	$\left(\frac{96}{141}\right)$	118	$\left(\frac{49}{110}\right)$	117	$\left(\frac{70}{134}\right)$	101	$\left(\frac{89}{134}\right)$	100	$\left(\frac{99}{143}\right)$
HOOP/ COLUMN										
0.05 Kg/M^2	199*	$\left(\frac{1250}{4650}\right)$***	188*	$\left(\frac{3670}{6670}\right)$***	197*	$\left(\frac{3050}{6420}\right)$***	198*	$\left(\frac{1280}{4630}\right)$***	200*	$\left(\frac{1070}{4520}\right)$***
0.15 Kg/M^2	170	$\left(\frac{62}{141}\right)$	188*	$\left(\frac{765}{6670}\right)$***	193	$\left(\frac{13}{134}\right)$	170	$\left(\frac{55}{134}\right)$	168	$\left(\frac{67}{143}\right)$
0.40 Kg/M^2	113	$\left(\frac{119}{141}\right)$	137	$\left(\frac{67}{110}\right)$	134	$\left(\frac{93}{134}\right)$	113	$\left(\frac{106}{134}\right)$	112	$\left(\frac{116}{143}\right)$
WRAP RADIAL RIB										
0.05 Kg/M^2	100	$\left(\frac{101}{141}\right)$	120	$\left(\frac{62}{110}\right)$	119	$\left(\frac{88}{134}\right)$	100	$\left(\frac{94}{134}\right)$	98	$\left(\frac{105}{143}\right)$
0.15 Kg/M^2	91	$\left(\frac{101}{141}\right)$	111	$\left(\frac{60}{110}\right)$	108	$\left(\frac{85}{134}\right)$	91	$\left(\frac{94}{134}\right)$	89	$\left(\frac{105}{143}\right)$
AVERAGE	133		147		150		133		132	

* VOLUME CONSTRAINED, OTHERWISE MASS CONSTRAINED

*** MASS RATIO - ALL OTHERS ARE DIAMETER (VOLUME) RATIOS.

$\left(\frac{x}{y}\right)$ WHERE: X IS THE REMAINING VOLUME (M^3) OR MASS (kg) NOT OCCUPIED BY THIS LSS,
Y IS THE AVAILABLE PAYLOAD VOLUME OR AVAILABLE PAYLOAD MASS.

TABLE VI-8 MAXIMUM LSS DIAMETERS (METERS)

T/M = 0.1 g 8 PERIGEE BURN CONSTANT ACCELERATION PUMP FED NOMINAL MIXTURE RATIO

LSS Configuration \ Propulsion Configuration	LO_2/RP-1 MAX. PERF.	$(\frac{x}{y})$	LO_2/RP-1 MIN. LENGTH	$(\frac{x}{y})$	N_2O_4/MMH MAX. PERF.	$(\frac{x}{y})$	N_2O_4/MMH MIN. LENGTH	$(\frac{x}{y})$
BOX TRUSS								
0.05 Kg/M^2	154	$(\frac{38}{134})$	153	$(\frac{55}{150})$	154	$(\frac{40}{136})$	150	$(\frac{48}{138})$
0.15 Kg/M^2	136	$(\frac{56}{134})$	136	$(\frac{70}{150})$	136	$(\frac{56}{136})$	133	$(\frac{62}{138})$
0.40 Kg/M^2	103	$(\frac{86}{134})$	102	$(\frac{102}{150})$	103	$(\frac{88}{136})$	100	$(\frac{92}{138})$
HOOP/COLUMN								
0.05 Kg/M^2	197*	$(\frac{1170}{5220})$***	200**		198*	$(\frac{1050}{5200})$***	199*	$(\frac{650}{4830})$***
0.15 Kg/M^2	172	$(\frac{60}{134})$	170	$(\frac{72}{150})$	172	$(\frac{54}{136})$	166	$(\frac{64}{138})$
0.40 Kg/M^2	118	$(\frac{112}{134})$	117	$(\frac{121}{150})$	118	$(\frac{106}{136})$	114	$(\frac{111}{138})$
WRAP RADIAL RIB								
0.05 Kg/M^2	100	$(\frac{95}{134})$	98	$(\frac{112}{150})$	100	$(\frac{97}{136})$	95	$(\frac{101}{138})$
0.15 Kg/M^2	89	$(\frac{96}{134})$	88	$(\frac{112}{150})$	89	$(\frac{98}{136})$	85	$(\frac{101}{138})$
AVERAGE	134		133		134		130	

* VOLUME CONSTRAINED, OTHERWISE MASS CONSTRAINED.

** THESE DIAMETERS ARE NOT BASED ON MAXIMIZED PAYLOAD VOLUME OR PAYLOAD MASS DUE TO LIMITATIONS IMPOSED UPON LSS DATA.

*** MASS RATIO - ALL OTHERS ARE DIAMETER (VOLUME) RATIOS

$(\frac{x}{y})$ X IS THE VOLUME (M^3) OR MASS (kg) NOT OCCUPIED BY THIS LSS.
Y IS THE AVAILABLE PAYLOAD VOLUME OR AVAILABLE PAYLOAD MASS.

TABLE VI-9 MAXIMUM LSS DIAMETERS (METERS)

T/M = 0.1 g 8 PERIGEE BURN PUMP FED
CONSTANT ACCELERATION NOMINAL MIXTURE RATIO

LSS Configuration \ Propulsion Configuration	LO_2/LCH_4 MAX. PERF.	$(\frac{x}{y})$	LO_2/LCH_4 MIN. LENGTH	$(\frac{x}{y})$	LO_2/LH_2 MAX. PERF.	$(\frac{x}{y})$	LO_2/LH_2 MIN. LENGTH	$(\frac{x}{y})$
BOX TRUSS								
0.05 Kg/M^2	154	$(\frac{33}{129})$	153	$(\frac{50}{145})$	165*	$(\frac{1580}{7380})$***	172*	$(\frac{280}{7280})$***
0.15 Kg/M^2	133	$(\frac{54}{129})$	132	$(\frac{71}{145})$	152	$(\frac{12}{110})$	151	$(\frac{29}{126})$
0.40 Kg/M^2	104	$(\frac{79}{129})$	102	$(\frac{97}{145})$	117	$(\frac{36}{110})$	116	$(\frac{48}{126})$
HOOP/COLUMN								
0.05 Kg/M^2	196*	$(\frac{2120}{5320})$***	200**		188*	$(\frac{2870}{7380})$***	195*	$(\frac{3830}{7280})$***
0.15 Kg/M^2	174	$(\frac{45}{129})$	172	$(\frac{63}{145})$	188*	$(\frac{479}{7380})$***	193	$(\frac{4}{126})$
0.40 Kg/M^2	118	$(\frac{99}{129})$	116	$(\frac{119}{145})$	138	$(\frac{66}{110})$	137	$(\frac{83}{126})$
WRAP RADIAL RIB								
0.05 Kg/M^2	101	$(\frac{90}{129})$	100	$(\frac{106}{145})$	115	$(\frac{65}{110})$	114	$(\frac{}{126})$
0.15 Kg/M^2	89	$(\frac{90}{129})$	88	$(\frac{107}{145})$	104	$(\frac{65}{110})$	103	$(\frac{81}{126})$
AVERAGE	134		133		145		148	

* VOLUME CONSTRAINED, OTHERWISE MASS CONSTRAINED.

** THESE DIAMETERS ARE NOT BASED ON MAXIMIZED PAYLOAD VOLUME OR PAYLOAD MASS DUE TO LIMITATIONS IMPOSED UPON LSS DATA.

*** MASS RATIO-ALL OTHERS ARE DIAMETER (VOLUME) RATIOS

$(\frac{x}{y})$ WHERE: X IS THE REMAINING VOLUME (M^3) OR MASS (kg) NOT OCCUPIED BY THIS LSS
Y IS THE AVAILABLE PAYLOAD VOLUME OR AVAILABLE PAYLOAD MASS

TABLE VI-10 MAXIMUM LSS DIAMETERS (METERS)

T/M = 0.1 g   1 PERIGEE BURN   PUMP FED
CONSTANT ACCELERATION   NOMINAL MIXTURE RATIO

LSS Configuration \ Propulsion Configuration	N_2O_4/MMH MAX. PERF.	$(\frac{x}{y})$	LO_2/LH_2 MAX. PERF.	$(\frac{x}{y})$	LO_2/LH_2 MIN. LENGTH	$(\frac{x}{y})$	LO_2/LCH_4 MAX. PERF.	$(\frac{x}{y})$	LO_2/LCH_4 MIN. LENGTH	$(\frac{x}{y})$
BOX TRUSS										
0.05 Kg/M^2	138	$(\frac{56}{134})$	164	(+)	163	$(\frac{28}{133})$	139	$(\frac{49}{128})$	138	$(\frac{64}{142})$
0.15 Kg/M^2	123	$(\frac{69}{134})$	143	$(\frac{19}{107})$	142	$(\frac{46}{133})$	124	$(\frac{62}{128})$	122	$(\frac{78}{142})$
0.40 Kg/M^2	91	$(\frac{97}{134})$	110	$(\frac{54}{107})$	109	$(\frac{81}{133})$	92	$(\frac{91}{128})$	90	$(\frac{107}{142})$
HOOP/COLUMN										
0.05 Kg/M^2	197*	$(\frac{1440}{3900})$***	186*	$(\frac{3190}{6130})$***	197*	$(\frac{2550}{6050})$***	195*	$(\frac{550}{4000})$***	200*	$(\frac{200}{3900})$***
0.15 Kg/M^2	152	$(\frac{77}{134})$	184	$(\frac{5}{107})$	183	$(\frac{33}{133})$	153	$(\frac{70}{128})$	151	$(\frac{86}{142})$
0.40 Kg/M^2	101	$(\frac{112}{134})$	128	$(\frac{70}{107})$	126	$(\frac{98}{133})$	103	$(\frac{105}{128})$	101	$(\frac{120}{142})$
WRAP RADIAL RIB										
0.05 Kg/M^5	89	$(\frac{99}{134})$	107	$(\frac{65}{107})$	106	$(\frac{91}{133})$	89	$(\frac{93}{128})$	88	$(\frac{107}{142})$
0.15 Kg/M^2	79	$(\frac{100}{134})$	96	$(\frac{65}{107})$	95	$(\frac{91}{133})$	80	$(\frac{94}{128})$	78	$(\frac{109}{142})$
AVERAGE	121		140		140		122		121	

* VOLUME CONSTRAINED, OTHERWISE MASS CONSTRAINED.

*** MASS RATIO - ALL OTHERS ARE DIAMETER (VOLUME) RATIOS.

$(\frac{x}{y})$ WHERE: X IS THE REMAINING VOLUME (M^3) OR MASS (kg) NOT OCCUPIED BY THIS LSS.
Y IS THE AVAILABLE PAYLOAD VOLUME OR AVAILABLE PAYLOAD MASS.

\+ BOTH PAYLOAD MASS AND PAYLOAD VOLUME CONSTRAINTS ARE MET SIMULTANEOUSLY.

TABLE VI-11 MAXIMUM LSS DIAMETERS (METERS)

T/M = 0.1 g — 8 PERIGEE BURNS, CONSTANT THRUST — PUMP FED, NOMINAL MIXTURE RATIO

LSS Configuration \ Propulsion Configuration	LO_2/LH_2 MAX. PERF.	$(\frac{x}{y})$	LO_2/LH_2 MIN. LENGTH	$(\frac{x}{y})$	LO_2/LCH_4 MAX. PERF.	$(\frac{x}{y})$	LO_2/LCH_4 MIN. LENGTH	$(\frac{x}{y})$
BOX TRUSS								
0.05 Kg/M^2	166*	$(\frac{780}{6980})$***	170	$(\frac{20}{135})$	151	$(\frac{41}{133})$	145	$(\frac{71}{156})$
0.15 Kg/M^2	149	$(\frac{15}{110})$	147	$(\frac{20}{135})$	133	$(\frac{57}{133})$	129	$(\frac{66}{156})$
0.40 Kg/M^2	116	$(\frac{52}{110})$	113	$(\frac{75}{135})$	100	$(\frac{89}{133})$	95	$(\frac{166}{156})$
HOOP/COLUMN								
0.05 Kg/M^2	188*	$(\frac{3880}{6980})$***	198*	$(\frac{3050}{6700})$***	197*	$(\frac{1390}{4890})$***	200**	
0.15 Kg/M^2	188*	$(\frac{380}{6980})$***	188	$(\frac{25}{135})$	167	$(\frac{58}{133})$	160	$(\frac{90}{156})$
0.40 Kg/M^2	136	$(\frac{68}{110})$	132	$(\frac{95}{135})$	114	$(\frac{105}{133})$	108	$(\frac{130}{156})$
WRAP RADIAL RIB								
0.05 Kg/M^2	112	$(\frac{66}{110})$	111	$(\frac{92}{135})$	95	$(\frac{96}{133})$	92	$(\frac{120}{156})$
0.15 Kg/M^2	102	$(\frac{66}{110})$	99	$(\frac{92}{135})$	88	$(\frac{94}{133})$	84	$(\frac{120}{156})$
AVERAGE	145		145		131		127	

* VOLUME CONSTRAINED, OTHERWISE MASS CONSTRAINED *** MASS RATIO - ALL OTHERS ARE DIAMETER (VOLUME) RATIOS

$(\frac{x}{y})$ WHERE: X IS THE REMAINING VOLUME (M^3) OR MASS (Kg) NOT OCCUPIED BY THIS LSS.
Y IS THE AVAILABLE PAYLOAD VOLUME OR AVAILABLE PAYLOAD MASS.

** THESE DIAMETERS ARE NOT BASED ON MAXIMIZED PAYLOAD VOLUME OR PAYLOAD MASS DUE TO LIMITATIONS IMPOSED UPON LSS DATA.

From the maximum average LSS diameter comparisons, several conclusions can be drawn:

1) As expected, the greater the surface density of the three LSS concepts, the lower the maximum LSS diameter.
2) A T/M of 0.05 g provides for maximum LSS diameters for constant acceleration and constant thrust, each with 8 perigee burns.
3) A T/M of 0.1 g provides for maximum LSS diameters for constant acceleration, 1 perigee burn transfers.
4) Maximum LSS diameters for an 8 perigee burn are generally greater than a 1 perigee burn strategy.
5) Constant acceleration provides for a greater maximum LSS diameter than constant thrust for the same T/M.
6) Maximum LSS diameters for maximum performance and minimum length propulsion configurations are within four percent of which maximum performance is higher.
7) The LO_2/LH_2 propellant combination provides the highest average LSS diameters for both tankage configurations, propulsion mode, burn strategy, and T/M range.

With the OTV burnout mass and LSS mass known, a final burnout thrust was calculated from the corresponding acceleration. This allowed LSS deployed diameter curves to be developed as a function of thrust level for each combination of vehicle and LSS.

Propulsion system sizing results indicated a LO_2/LH_2 maximum performance vehicle and a N_2O_4/MMH minimum length vehicle are the best and worst performers, respectively, based on a deliverable payload mass. Presented in Figure VI-3 is LSS diameter versus thrust level for LO_2/LH_2, maximum performance vehicle with parametric LSS. Inspection of Figure VI-3 reveals two types of trends for LSS diameters which result from the 100% utilization of payload volume or payload mass. The top two curves (HC-0.15 and BT-0.05) represent volume limited LSS in the Orbiter cargo bay. The deliverable diameter of volume limited LSS are relativity insensitive to thrust level. This insensitivity occured because of the small change in stage length for pump-fed vehicles as shown in Figures V-13 and V-14. As stage length changes only slightly over the thrust range, so does that available payload volume. Only small diameter changes ($<$ 2M) were determined when developing maximum LSS diameter points over the thrust range of interest. The second LSS diameter trend is shown in the remaining five curves. All of these LSS were mass limited in the cargo bay. Below thrust levels of 2225 N, dramatic decreases in LSS deployed diameter were seen because of the vehicle increased delta velocity requirements below the acceleration level (0.015 g's). LSS deployed diameter decreased above thrust levels of 4450 N due to the acceleration mass impacts on the LSS. The resultant optimum thrust level

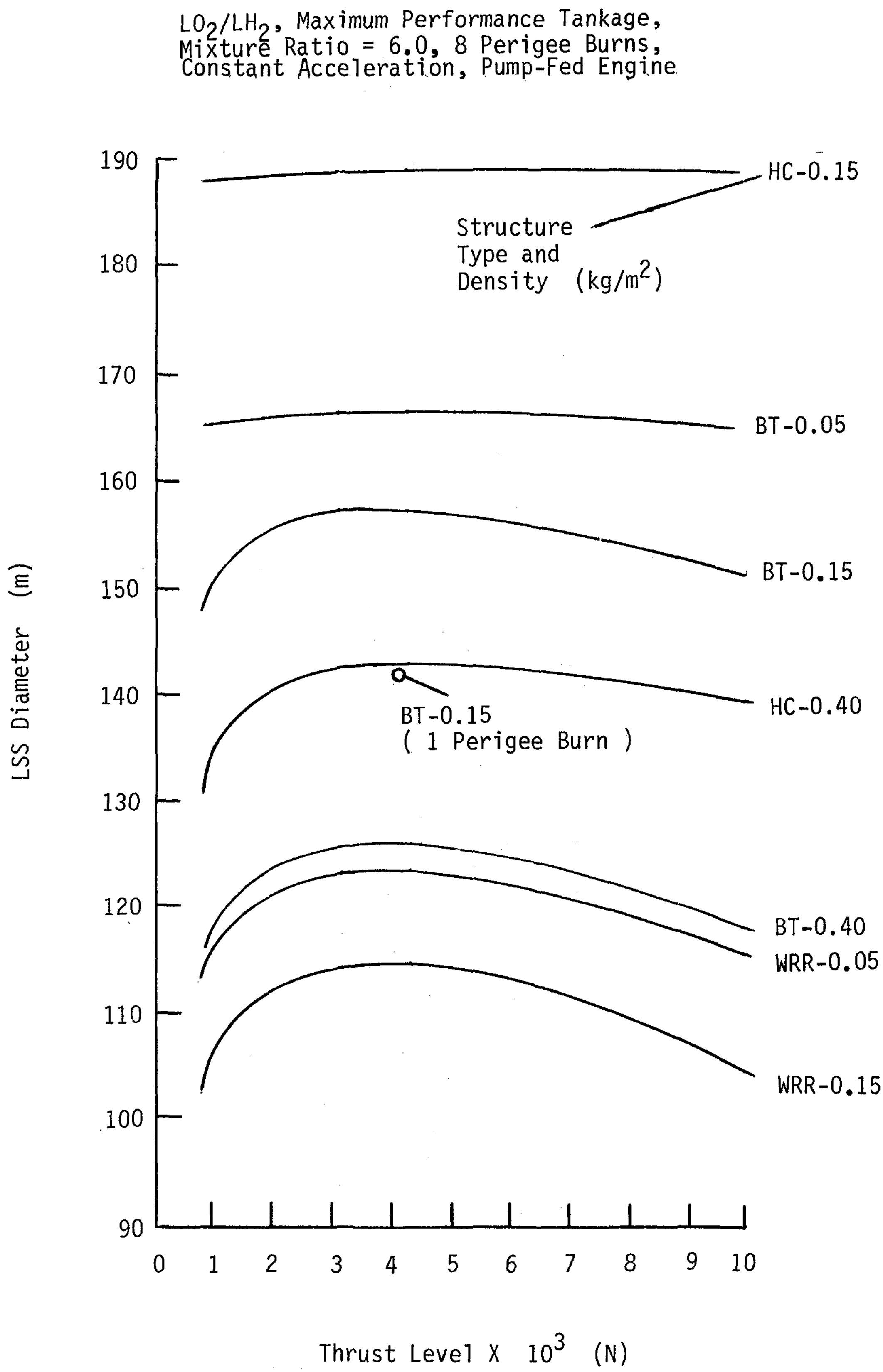


FIGURE VI - 3 - Effect of Thrust Level on LSS Diameter for LO_2/LH_2 OTV

range for all structures is between 3100 to 4200N. Included in Figure VI-3 is a comparison point of a 1 perigee burn, constant acceleration, pump-fed, minimum length, LO_2/LH_2 vehicle. As shown, the 8 burn transfer strategy delivered approximately a 10% greater LSS diameter than a 1 burn strategy at a thrust level of 4450 N. On the other end of the performance spectrum is a minmum length, N_2O_4/MMH OTV. This vehicle's delivery capability is shown in Figure VI-4 for the various LSS. Similar to the LO_2/LH_2 vehicle, the N_2O_4/MMH vehicle has an optimum thrust level range of 3100 to 4200 N for all structures.

To demonstrate the independence of propellant combination and tankage configuration on optimum thrust level, Figure VI-5 presents LSS diameter versus thrust level for the expandable box truss with 0.05 Kg/M^2 surface density. The top two curves in Figure VI-5 represent volume-limited structures where as the remaining curves are mass-limited structures. All the mass-limited curves have an optimum thrust level of 3100 to 4200N independent of propellent combination and tankage configuration.

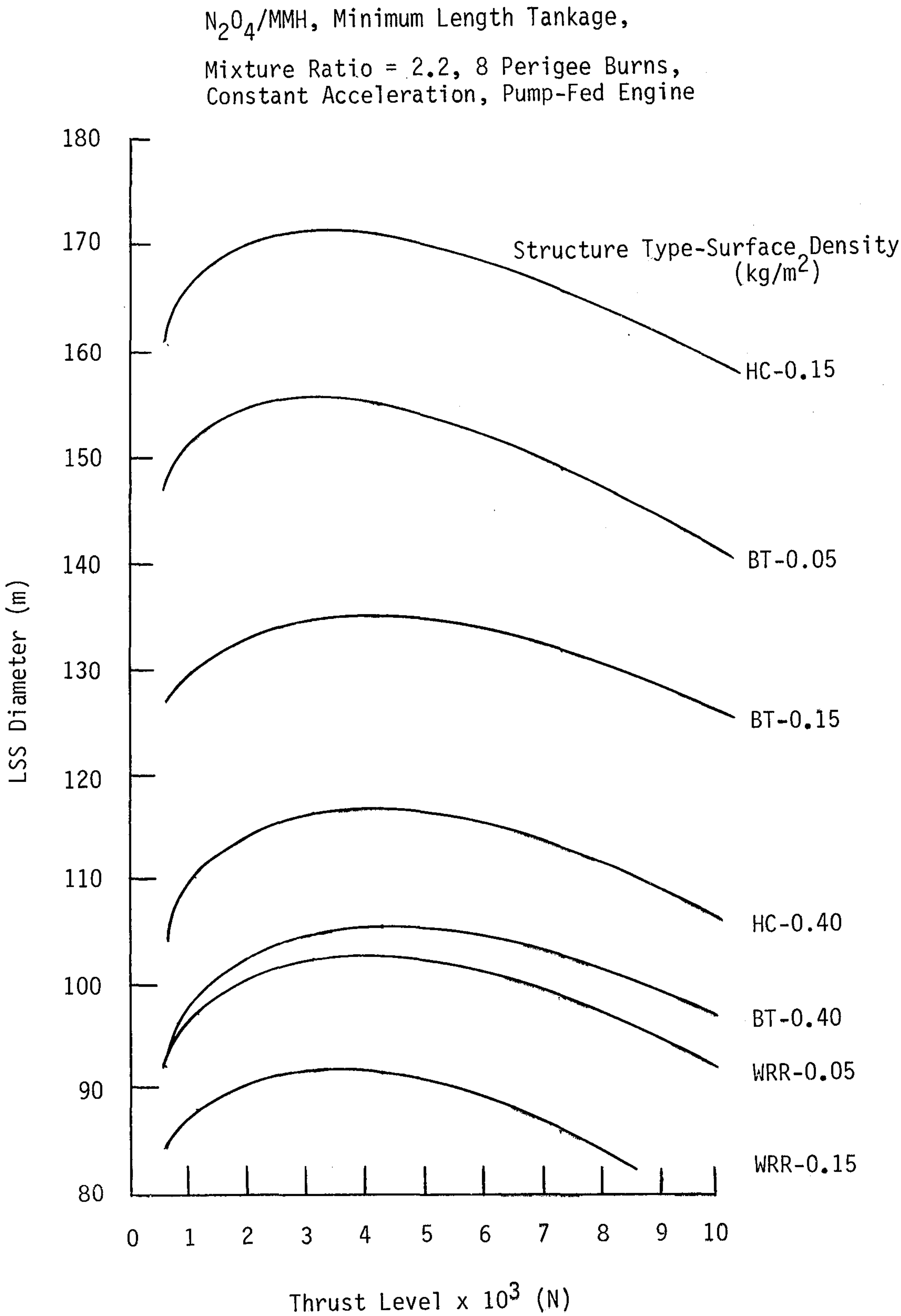


FIGURE VI - 4 - Effect of Thrust Level on LSS Diameter for N_2O_4/MMH OTV.

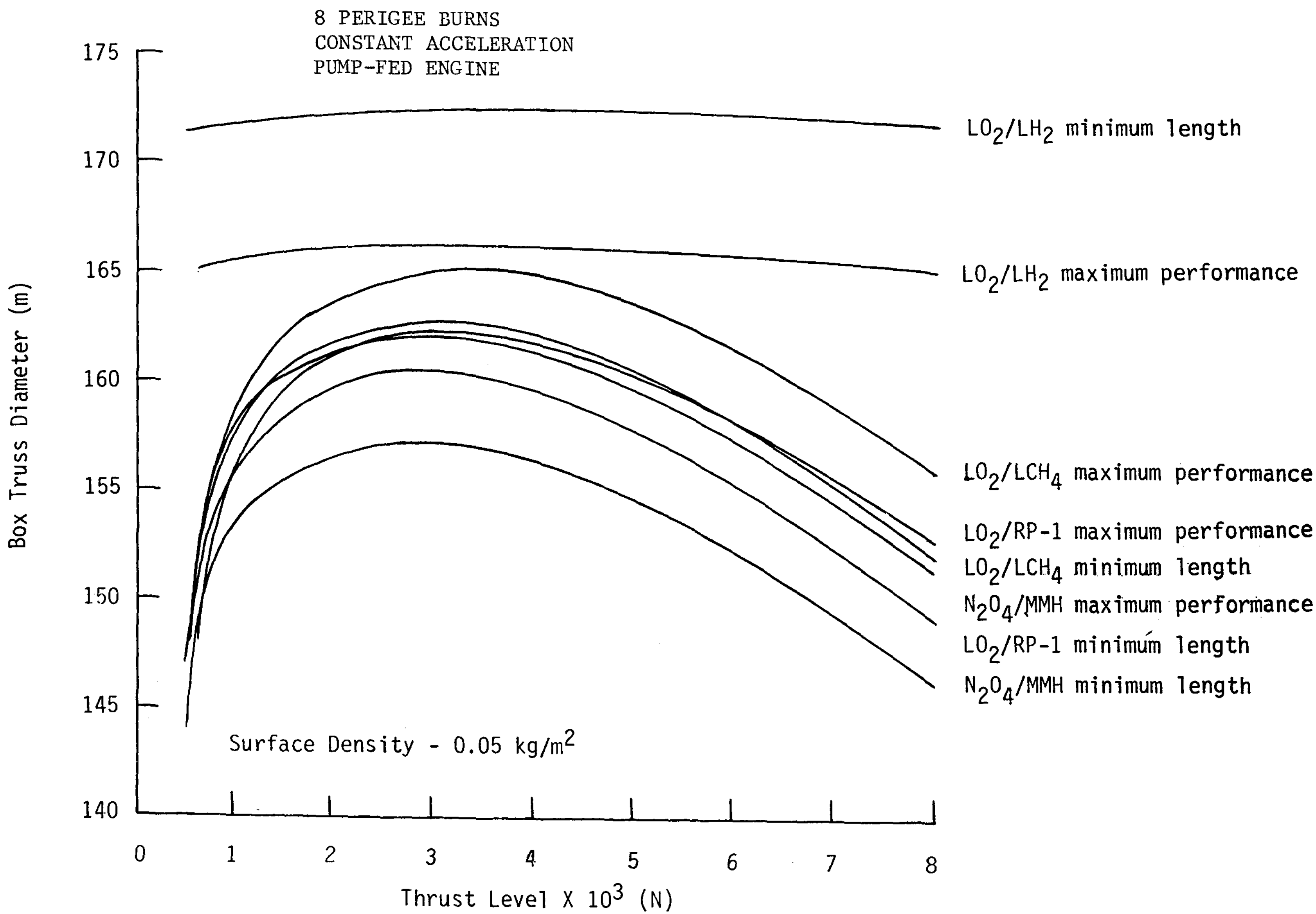


FIGURE VI - 5 - Effect of Thrust Level on Box Truss Diameter for Various Propellant Combinations and Tankage Configurations

VII. SUMMARY OF RESULTS & CONCLUSIONS

This study has investigated the interactions of large space systems and primary propulsion. Three LSS concepts with a broad range of diameters, surface densities and acceleration rates were compared to 175 primary propulsion systems in order to identify propulsion system characteristic which maximize deployed LSS diameter. The three LSS concepts which baselined this study are wrap radial rib, hoop and column, and expandable box truss.

For these baseline configurations, parametric studies of LSS mass as a function of area and thrust-to-mass ratio were conducted to determine the effect of steady state and transient thrust on structural mass.

Seventeen typical box truss configurations with diameters ranging from 35 to 194 m and surface densities ranging from 0.05 to 3.42 kg/m^2 were analyzed. At a typical low-thrust T/M ratio of 0.05 g's the structural mass impact (i.e., the additional mass above that associated with minimum gage structural elements) was relatively small (20% or less) for fifteen of the seventeen cases. Exceptions were the maximum diameter (194 m/0.05 kg/m^2) and the maximum surface density (71 m/3.42 kg/m^2) cases where the structural mass impacts were 70% and 90% respectively.

Fourteen typical radial rib configurations with diameters ranging from 35 to 194 m and surface densities ranging from 0.05 to 0.15 kg/m^2 were analyzed. At a typical low-thrust T/M ratio of 0.05 g's there was no structural mass impact on any of the configurations which were analyzed (structural mass impact occurred at a T/M of 0.055 g's on the 194m/0.15 kg/m^2 configuration). The relatively high allowable acceleration at large diameters is due to stiffness criteria which increases the size of cantilevered ribs as diameter increases. Additionally, the radial rib concept was not sized for the higher surface densities of 0.40 and 3.42 kg/m^2.

Nine typical hoop and column configurations with diameters ranging from 50 to 200 m and surface densities ranging from 0.05 to 0.40 kg/m^2 were analyzed. At a typical low-thrust T/M ratio of 0.05 g's the structural mass impact was relatively small (12% or less) for six of the nine cases. Exceptions were the maximum diameter (200 m) cases with surface densities of 0.05, 0.15, and 0.40 kg/m^2 where the structural mass impacts at 0.05 g's were 23%, 40%, and 134% respectively.

All of the LSS configurations exhibited a common trend after the minimum gage structural mass was affected by acceleration, i.e., an exponential increase in structural mass as T/M was increased. For a given diameter and surface density the mass change is relatively small for the box truss and the hoop and column over a wide range of T/M and, with the exception of the maximum diameter and/or surface density cases noted above, only small reductions in structural mass are realized at T/M ratios below 0.05 g's. For the wrap radial rib, the structural mass change is very sensitive to T/M and the mass increases are large over a small range of T/M.

Typical box truss, radial rib, and hoop and column configurations were analyzed to determine the effect of start and shutdown transients on structural mass. These analyses were conducted for a constant thrust burn strategy. For this strategy the most critical start condition from a dynamic standpoint is the apogee burn. Results of the analyses indicated an average structural mass impact (relative to steady state) of 10% for a step thrust input and negligible mass impact for ramps equal in time to 2/3 of the fundamental period of the combined LSS-OTV. For the LSS configurations considered, start times which produced negligible impact ranged from 0.2 to 10 seconds. Shutdown transient analyses indicated that an instantaneous thrust cutoff at the end of the apogee burn (critical condition) produced negligible structural mass impact.

The three structural concepts were evaluated to determine their applicability to multi-point thrust application. The box truss, with its large number of hard points for attachment, provides complete flexibility for location of the propulsion system. The hoop and column concept requires that propulsion system locations be limited to the column and the hoop. The radial rib antenna has only one hard point - the hub. Therefore, multi-point thrust is not applicable to the radial rib concept.

The box truss, structural mass impact results for steady state multi-point thrust application are summarized as follows. By utilizing a 5 point thrust application, a factor of ≈ 2 increase in thrust can be allowed without a change in structural mass impact. By going from a 5 point to a 9 point thrust application, less than a 50% increase in thrust can be realized for no change in structural mass impact. The hoop and column, steady state multi-point thrust application results show that by utilizing a 5 point thrust application, less than a factor of two increase in thrust can be allowed without a change in structural mass impact. The 9 point thrust application shows only a small improvement over the 5 point. Like the box truss, the results indicate that for these size ranges, multi-point thrust does not provide enough of a performance enhancement to warrant the added stage complexity.

Parametric analyses were performed to determine deliverable payload mass and engine burn times as a function of T/M, propulsion system performance, and number of perigee burns for transfer from low earth orbit (LEO) to geosynchronous earth orbit (GEO). Three thrust models; impulsive, constant thrust, and constant acceleration with ISP, number of burns, and T/M as parameters were studied as possible trajectory strategies. Several conclusions were drawn from the various trajectory strategies. First, multiple perigee burns can significantly reduce the ideal ΔV requirement for geosynchronous missions. Utilization of multiple burns lowers the required ideal velocity increment by reducing the gravity losses accumulated during the thrusting segments. Reduction of the gravity loss is a direct result of the negative to positive change in the flight path angle (FPA) over all but the first perigee burn. The second conclusion that can be drawn is that the constant acceleration propulsion mode offers advantages in ideal velocity requirements at certain T/M values over constant thrust cases for both 1 and 8 perigee burn transfers. It is clear from the trajectory parameter sensitivities that the T/M ratio is by far the principal driver in the trajectory design for low thrust systems with mass fraction as the second most important variable. The number of perigee burns has a significant impact on V requirement, trip time, and delivered payload. The least important Δ parameter appears to be Isp. However, change in Isp still impact payload mass.

The characteristics of several primary propulsion stages that are packaged in the Orbiter cargo bay and are used to deliver LSS from low earth orbit (LEO) to geosynchronous earth orbit (GEO) were determined. The characteristics include mass fraction, stage length, stage mass, and center of gravity position. Stage characteristics were generated parametrically as a function of thrust-to-mass ratio for oxygen/hydrogen, oxygen/methane, oxygen/kerosene, and nitrogen tetroxide/monomethylhydrazine over a selected acceleration range compatible with the LSS data, for both pump-fed and pressure-fed engines. The conclusion from the stage characteristic data suggest an 8 perigee burn, constant acceleration, pump-fed engine, primary propulsion system will maximize LSS deployed diameter.

Propulsion system comparisons were performed to provide insight as to how the primary propulsion system characteristics, orbit transfer techniques, LSS mass and area, Shuttle cargo bay packaging, and engine technology are interactive. The relative merit of the various primary propulsion system characteristics were established at T/M ratios of 0.01, 0.05 and 0.10 g's.

From these comparisons, several conclusions can be drawn:

1) As expected, the greater the surface density of the three LSS concepts, the lower the maximum LSS diameter;
2) A T/M of 0.05 g provides for maximum LSS diameters for constant acceleration and constant thrust, each with 8 perigee burns;
3) A T/M of 0.1 g provides for maximum LSS diameters for constant acceleration, 1 perigee burn transfers
4) Maximum LSS diameters for an 8 perigee burn are generally greater than a 1 perigee burn strategy;
5) Constant acceleration provides for a greater maximum LSS diameter than constant thrust for the same T/M;
6) Maximum LSS diameters for maximum performance and minimum length propulsion configurations are within four percent of which maximum performance is higher; and
7) The LO_2/LH_2 propellant combination provides the highest average maximum LSS diameter for both tankage configurations, propulsion mode, burn strategy, and T/M range.

Analyses were conducted to determine deployed LSS diameter as a function of thrust level for various combinations of OTV and LSS. Results indicated that, based on a single Shuttle flight with a LEO to GEO orbit transfer, the optimum OTV final thrust level range to maximize delivered LSS diameter (if payload mass limited) is between 3100 to 4200N and the maximum performance tankage configuration delivers the maximum deployed LSS diameter. This range is relatively independent of the following:

1) Propellant Combination;
2) Tankage Configuration;
3) Mixture Ratio;
4) Type of LSS; and
5) Type of LSS nonstructural surface.

However, if the spacecraft is volume limited in the Orbiter cargo bay then the maximum LSS diameter is relatively insensitive to thrust level over the range studied and the minimum length tankage configuration delivers the maximum deployed LSS diameter.

The following stage characteristics are reemphasized which deliver the maximum LSS diameter based on the results of this study. These characteristics are:

1) LO_2/LH_2 propellant combination
2) Pump-fed single engine, and
3) Constant acceleration, 8 perigee burn orbit transfer strategy

APPENDIX A

ENGINE DATA

Pressure-fed and pump-fed engine data for each of the propellant combinations at six thrust levels over the thrust range of interest were supplied by NASA-LeRC. Engine cycle and chamber pressure assumptions used in generating the data were as follows:

Pressure-Fed Engines: Chamber Pressure = 69 N/cm^2 for all propellant combinations and thrust levels.

Pump-Fed Engines:

N_2O_4/MMH: Gas Generator Cycle

LO_2/RP-1: Gas Generator Cycle

LO_2/LH_2: Expander Cycle

LO_2/LCH_4: Expander Cycle

THRUST LEVEL (N)	CHAMBER PRESSURE (N/cm^2)			
	N_2O_4/MMH	LO_2/RP-1	LO_2/LH_2	LO_2/LCH_4
445	69	69	69	69
1334	186	186	221	209
2224	269	269	345	303
4448	448	448	638	517
13344	607	607	965	724
31136	827	827	1379	1034

APPENDIX A

ENGINE DATA (Continued)

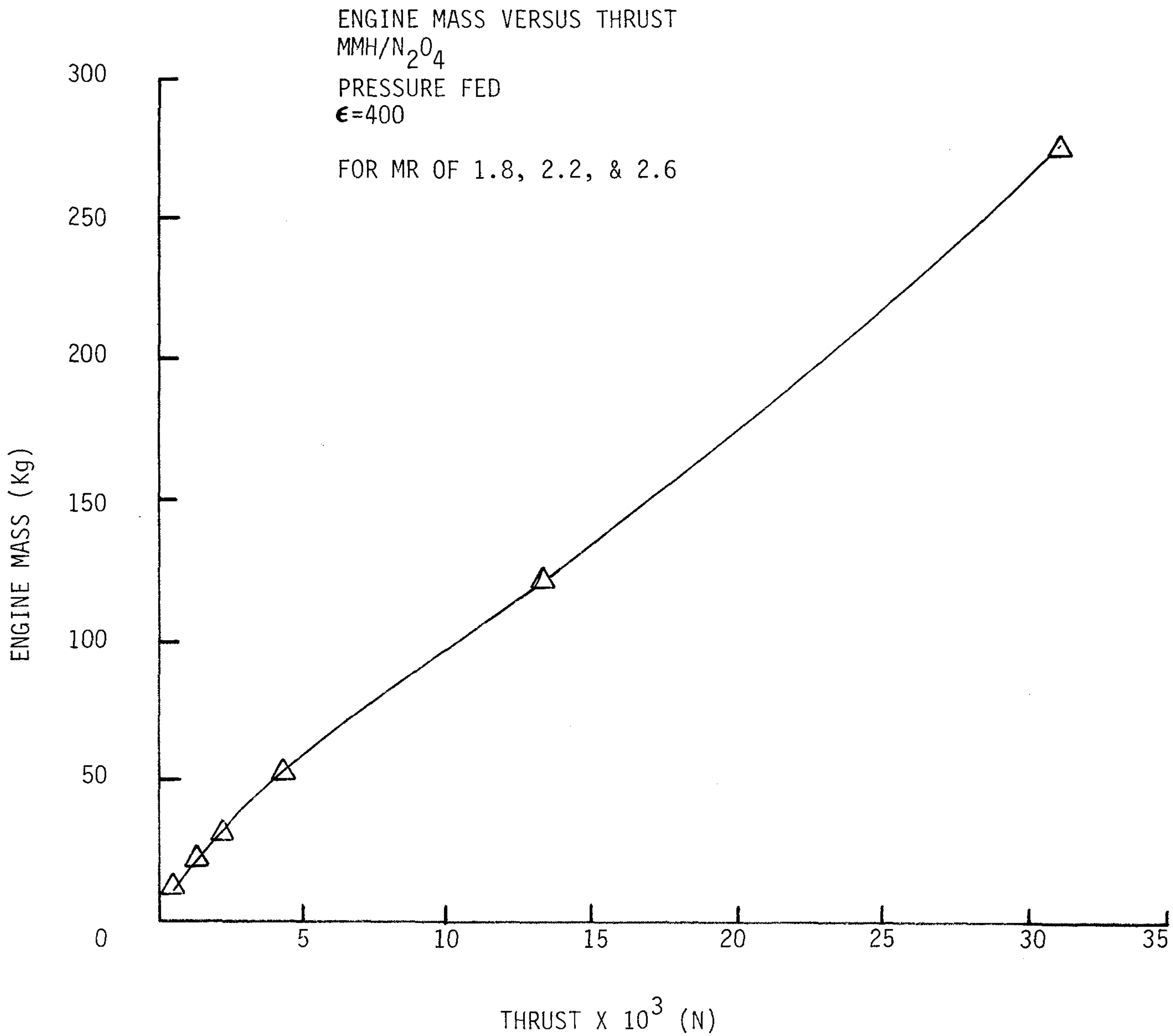
The engine data has been plotted for ease of use in the Section V parametric analysis. Engine mass, length with nozzle retracted, and vacuum specific impulse are plotted versus thrust level. The parametrics for the engine data figures are the four propellant combinations each with three mixture ratios, see Table V-1, for pump-fed and pressure-fed engines. In some instances, a maximum of 3% engine data variation with mixture ratio occurs at 31,150 N; therefore, the mixture ratio is an insignificant parameter and the data is expressed by a single (intermediate mixture ratio) curve.

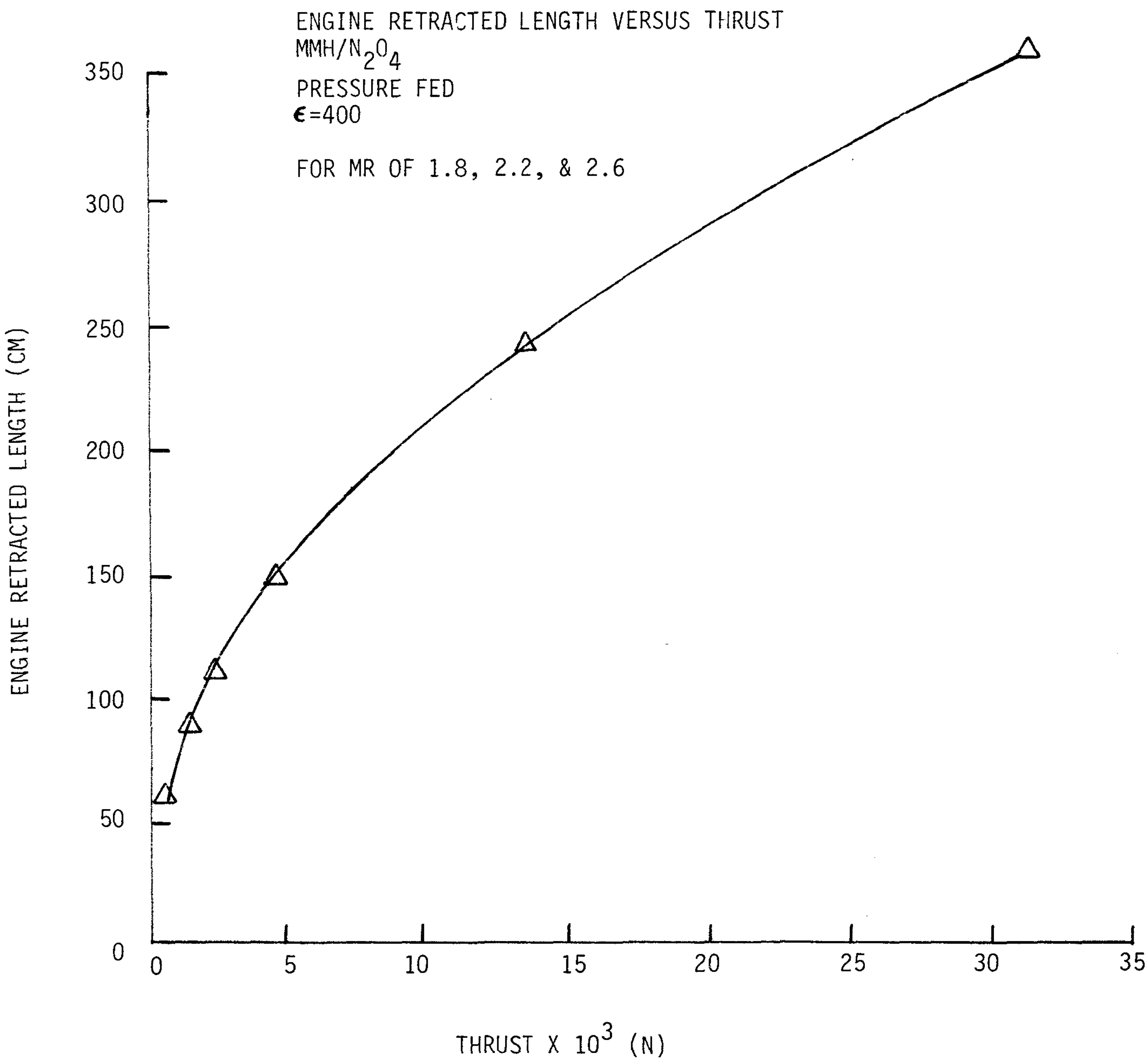
The order in which the figures are arranged for each propellant combination is displayed below in a generic outline. The figures are subdivided into the four propellant combinations which are arranged as follows: nitrogen tetroxide/monomethylhydrazine, N_2O_4/MMH; oxygen/kerosene, LO_2/RP-1; oxygen/hydrogen, LO_2/LH_2; and oxygen/methane, LO_2/LCH_4.

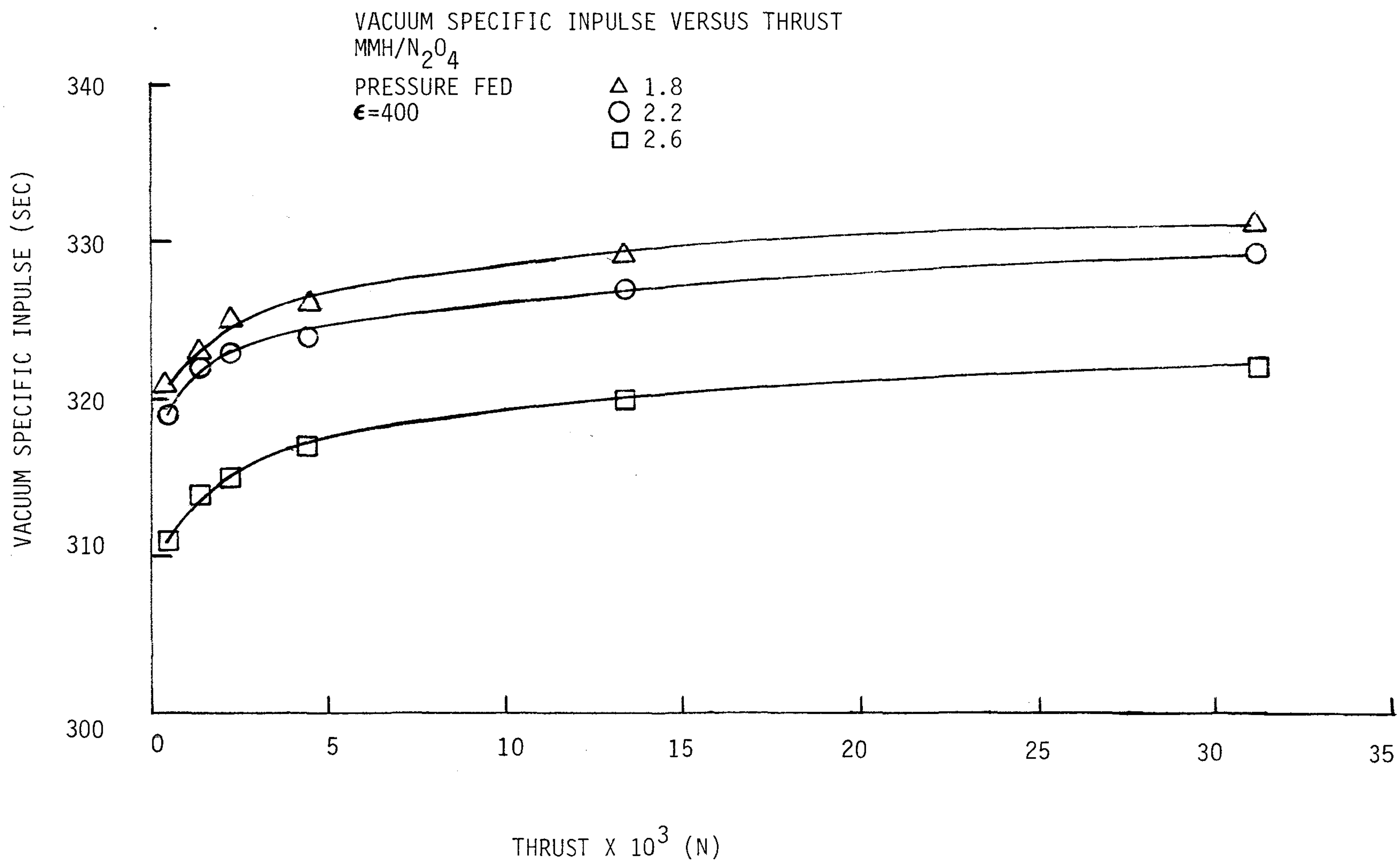
Engine Mass versus Thrust
Pressure-Fed, Pump-Fed

Engine Retracted Length versus Thrust
Pressure-Fed, Pump-Fed

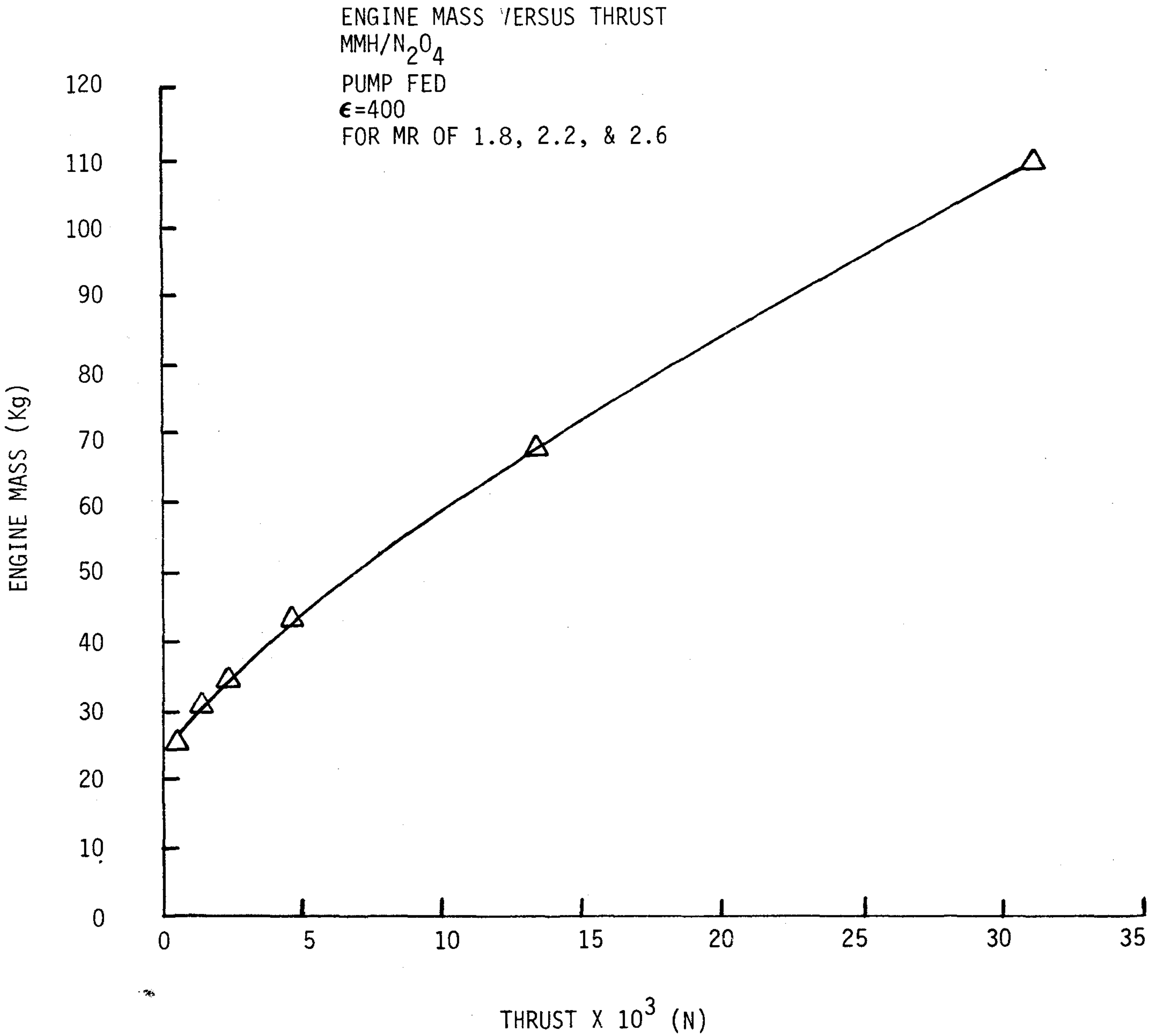
Vacuum Specific Impulse versus Thrust
Pressure-Fed, Pump-Fed

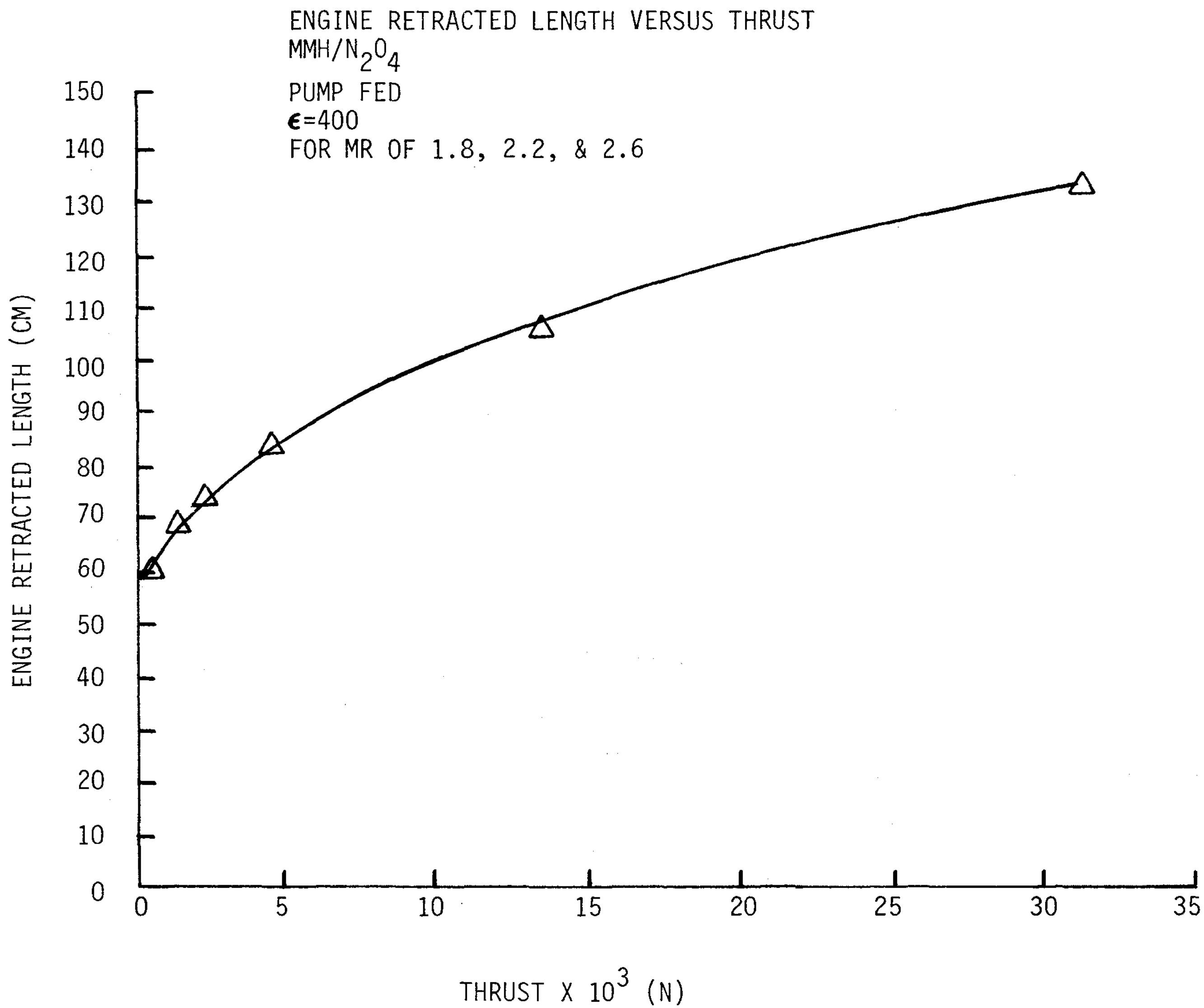

ENGINE MASS VERSUS THRUST
MMH/N_2O_4
PRESSURE FED
ϵ=400
FOR MR OF 1.8, 2.2, & 2.6
ENGINE MASS (Kg)
300
250
200
150
100
50
0
5
10
15
20
25
30
35
THRUST X 10^3 (N)

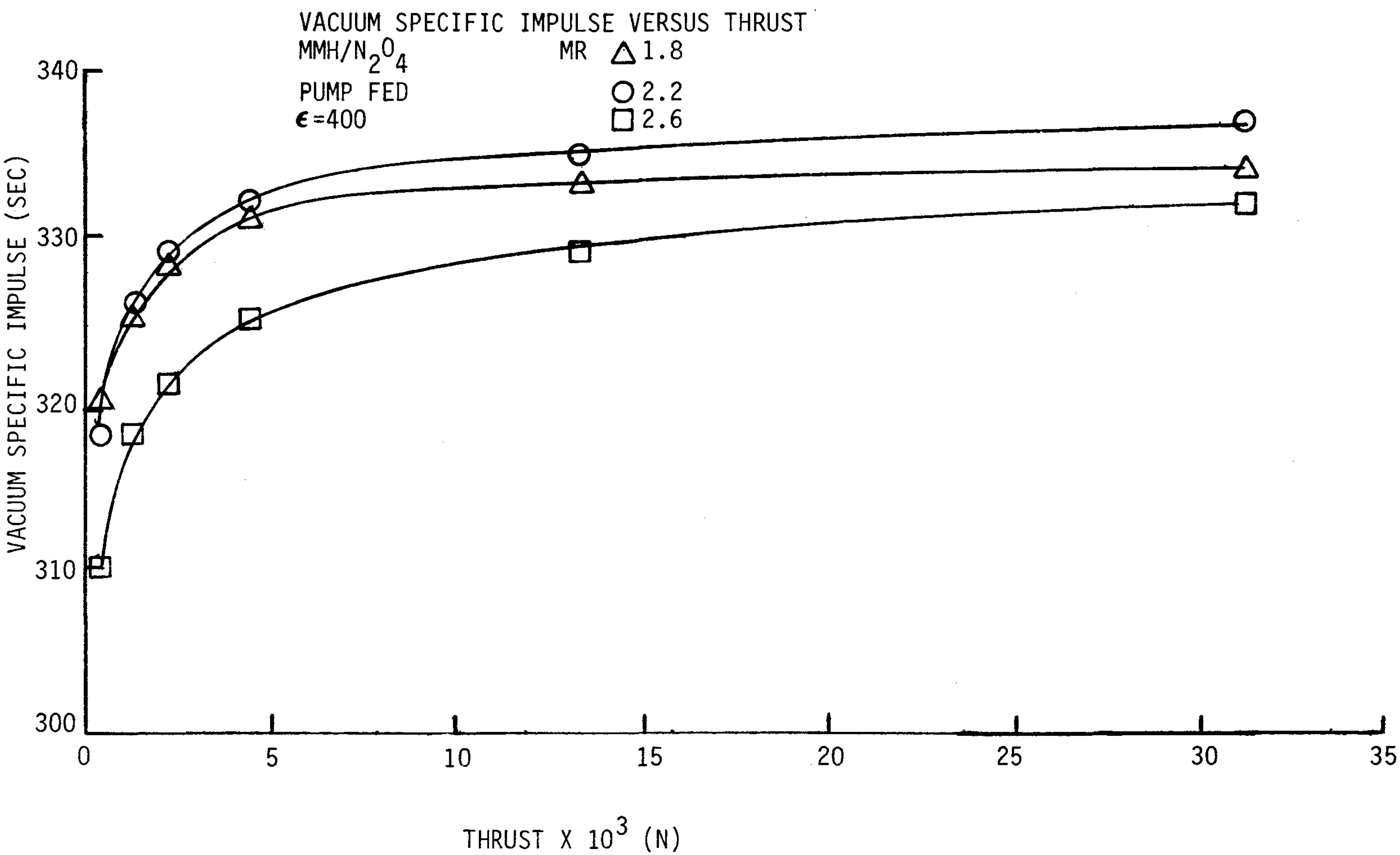

ENGINE RETRACTED LENGTH VERSUS THRUST
MMH/N_2O_4
PRESSURE FED
ϵ=400
FOR MR OF 1.8, 2.2, & 2.6
ENGINE RETRACTED LENGTH (CM)
0
50
100
150
200
250
300
350
0
5
10
15
20
25
30
35
THRUST X 10^3 (N)

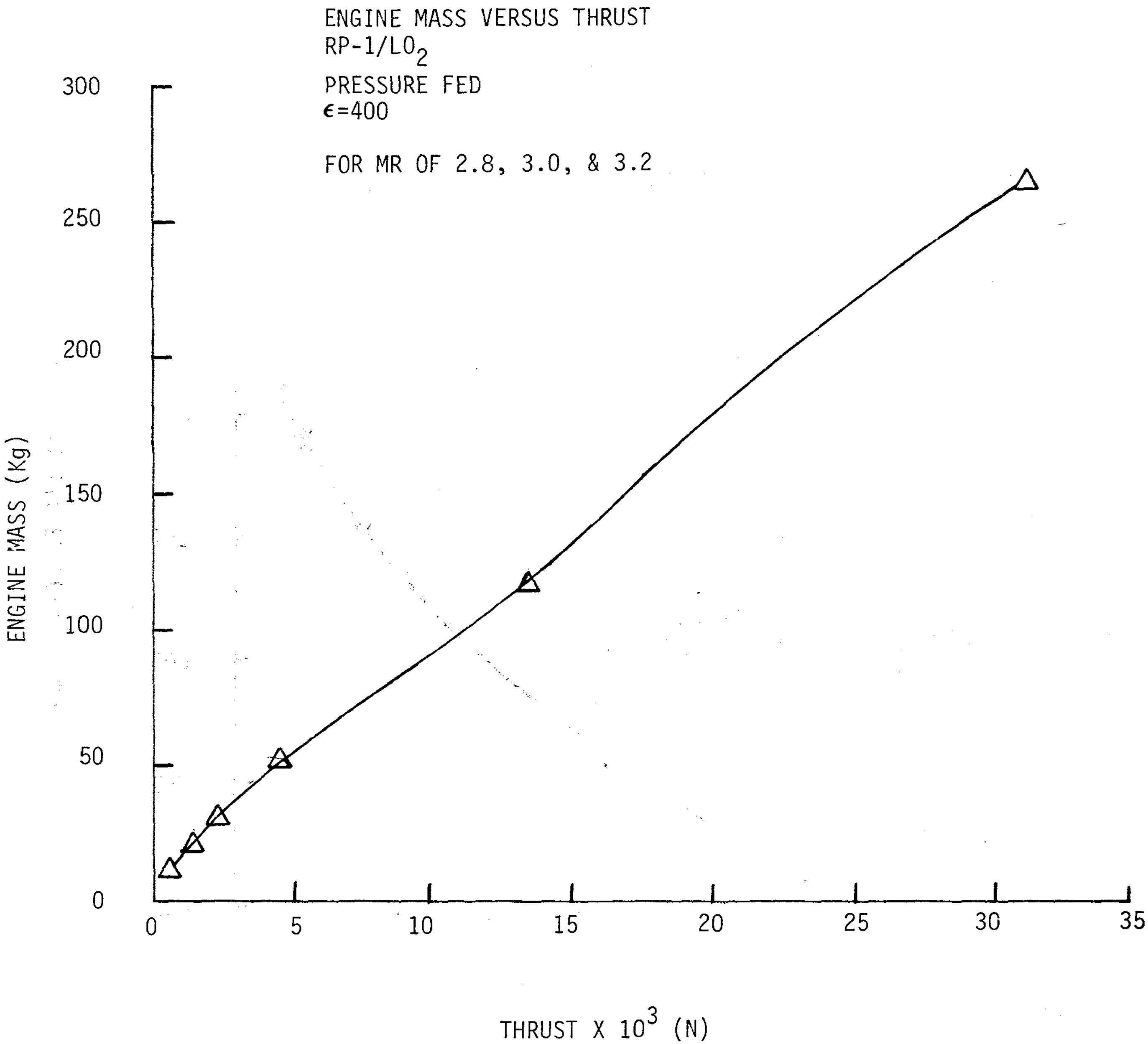


VACUUM SPECIFIC INPULSE VERSUS THRUST
MMH/N2O4
PRESSURE FED
ϵ=400
△ 1.8
○ 2.2
□ 2.6
VACUUM SPECIFIC INPULSE (SEC)
340
330
320
310
300
0
5
10
15
20
25
30
35
THRUST X 10^3 (N)

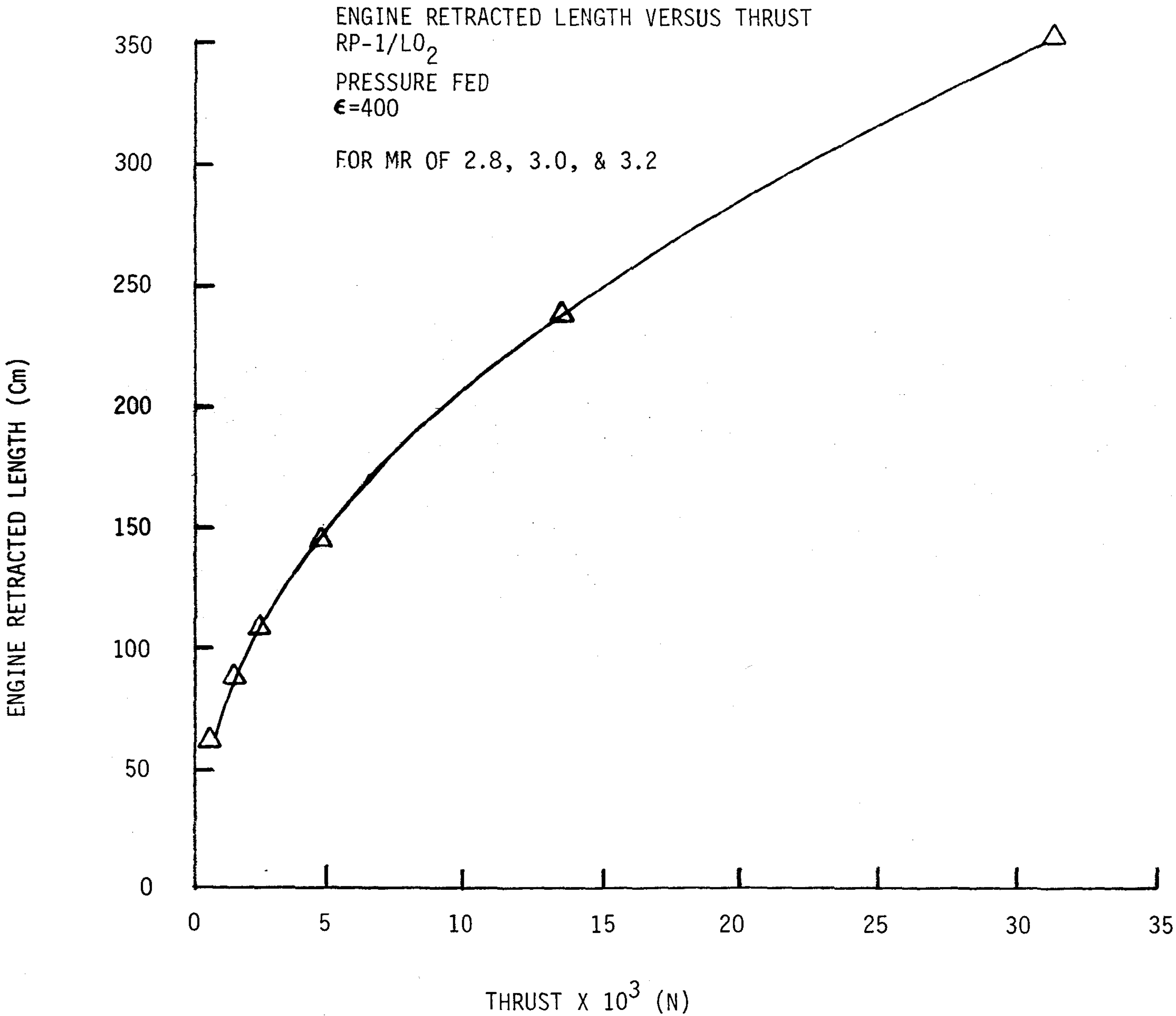

ENGINE MASS VERSUS THRUST
MMH/N2O4
PUMP FED
ϵ=400
FOR MR OF 1.8, 2.2, & 2.6
ENGINE MASS (Kg)
0
10
20
30
40
50
60
70
80
90
100
110
120
0
5
10
15
20
25
30
35
THRUST X 10^3 (N)


ENGINE RETRACTED LENGTH VERSUS THRUST
MMH/N2O4
PUMP FED
ϵ=400
FOR MR OF 1.8, 2.2, & 2.6
ENGINE RETRACTED LENGTH (CM)
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
0
5
10
15
20
25
30
35
THRUST X 10^3 (N)

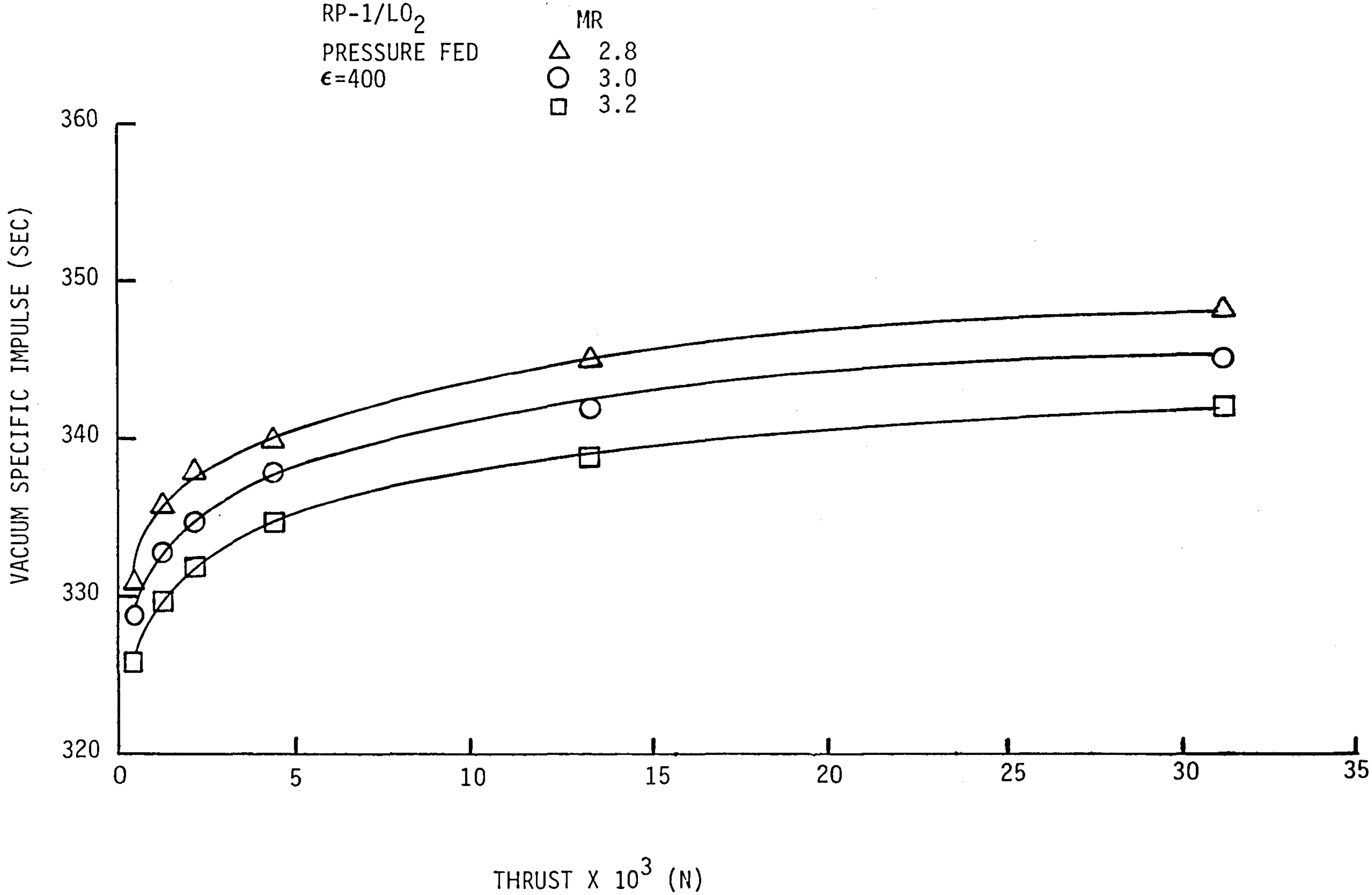

VACUUM SPECIFIC IMPULSE VERSUS THRUST
MMH/N_2O_4
PUMP FED
ϵ=400
MR
1.8
2.2
2.6
VACUUM SPECIFIC IMPULSE (SEC)
340
330
320
310
300
0
5
10
15
20
25
30
35
THRUST X 10^3 (N)

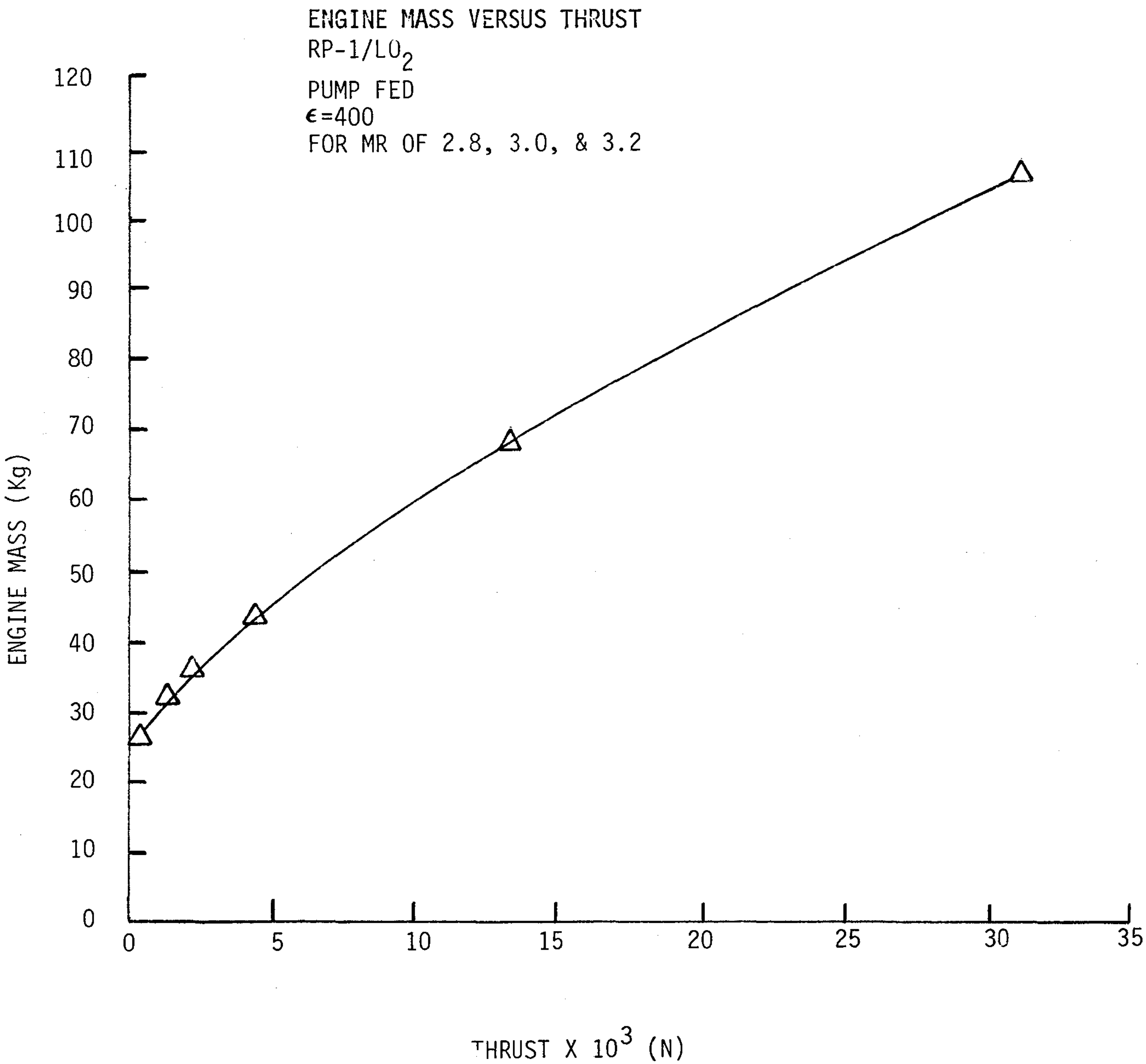


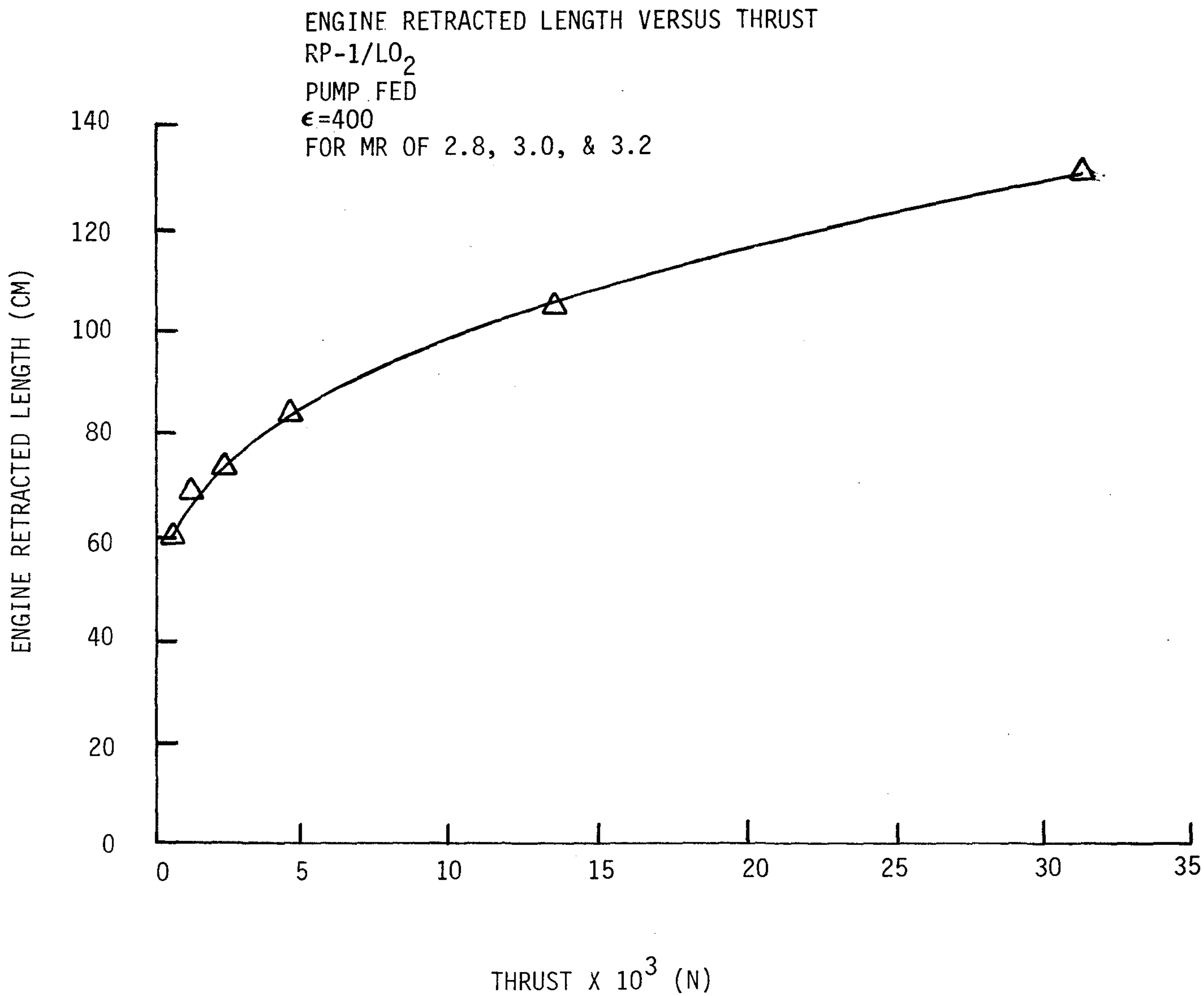
ENGINE MASS VERSUS THRUST
RP-1/LO2
PRESSURE FED
ϵ=400
FOR MR OF 2.8, 3.0, & 3.2
ENGINE MASS (Kg)
300
250
200
150
100
50
0
0
5
10
15
20
25
30
35
THRUST X 10^3 (N)


ENGINE RETRACTED LENGTH VERSUS THRUST
RP-1/LO2
PRESSURE FED
ϵ=400
FOR MR OF 2.8, 3.0, & 3.2
ENGINE RETRACTED LENGTH (Cm)
THRUST X 10^3 (N)
0
50
100
150
200
250
300
350
5
10
15
20
25
30
35

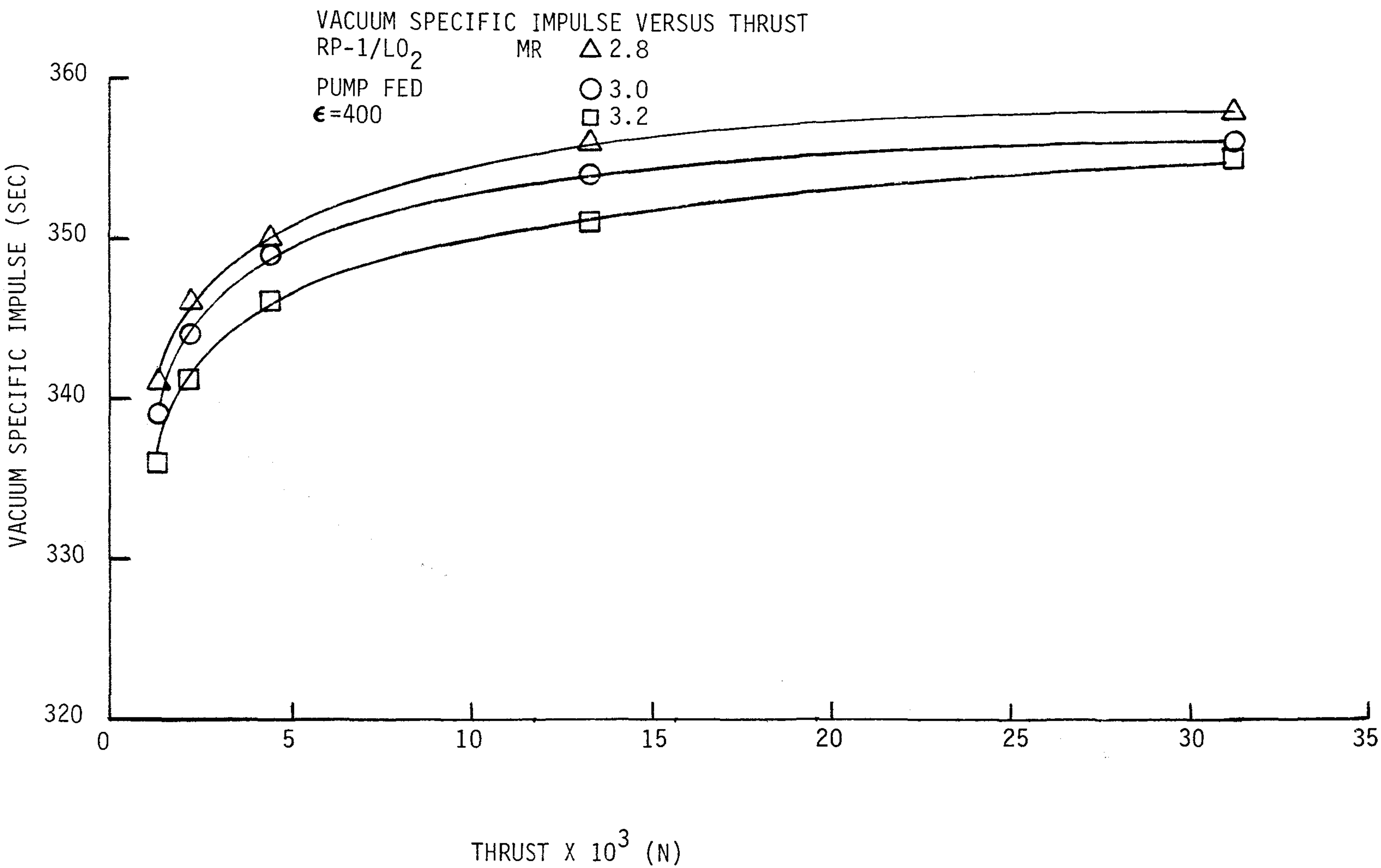
VACUUM SPECIFIC IMPULSE VERSUS THRUST

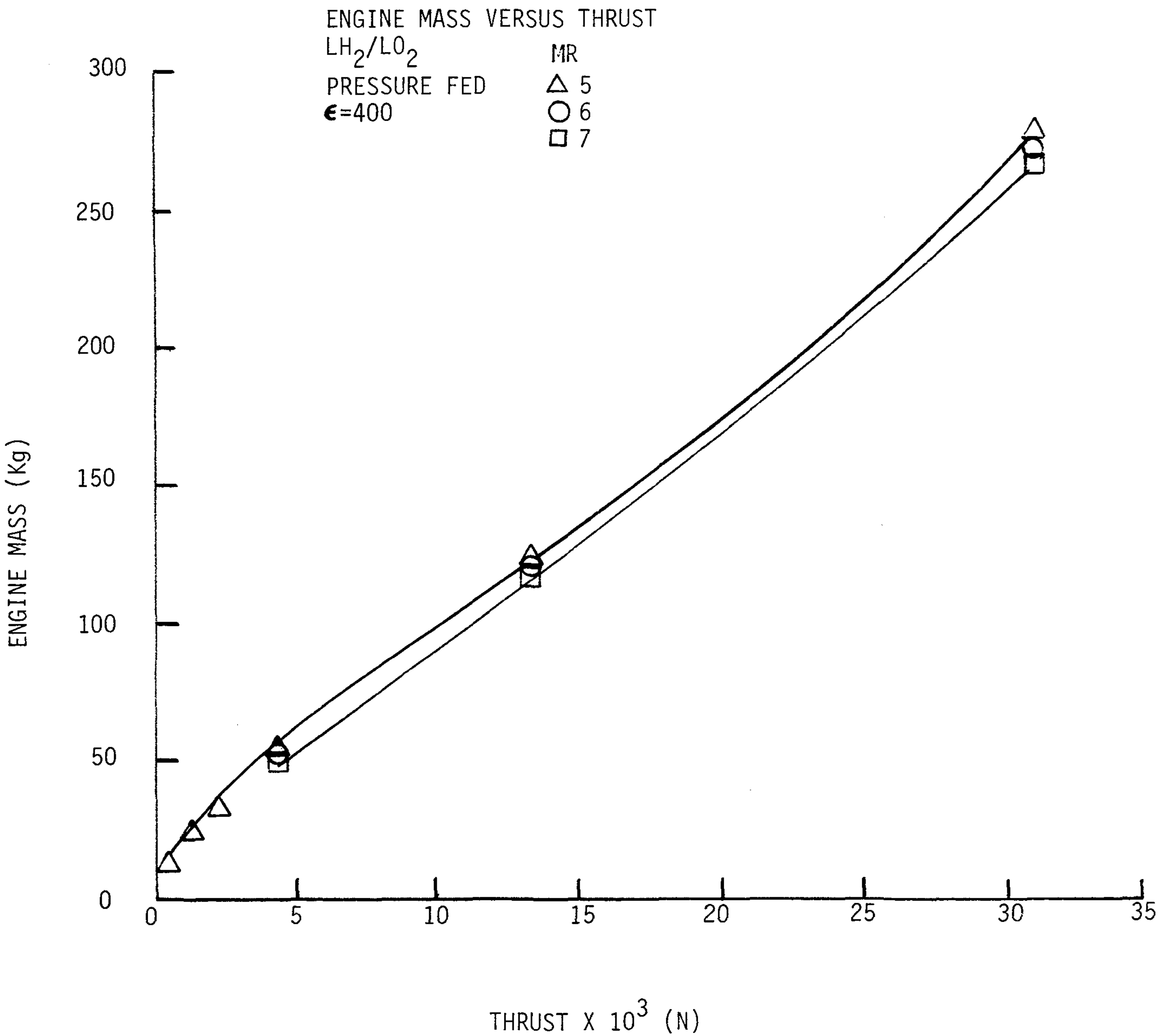



ENGINE MASS VERSUS THRUST
RP-1/LO2
PUMP FED
ϵ=400
FOR MR OF 2.8, 3.0, & 3.2
ENGINE MASS (Kg)
THRUST X 10^3 (N)
0
10
20
30
40
50
60
70
80
90
100
110
120
0
5
10
15
20
25
30
35

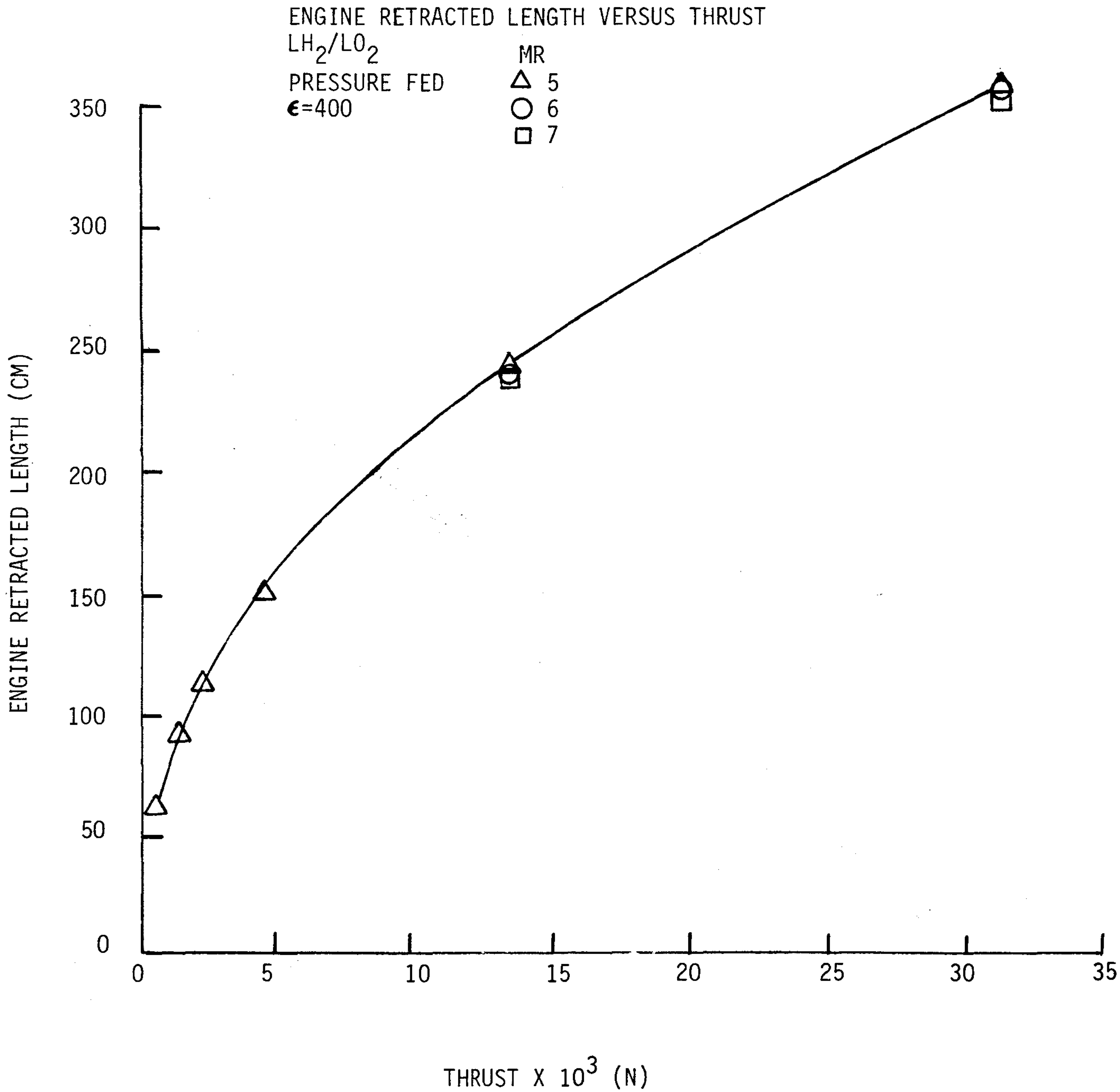


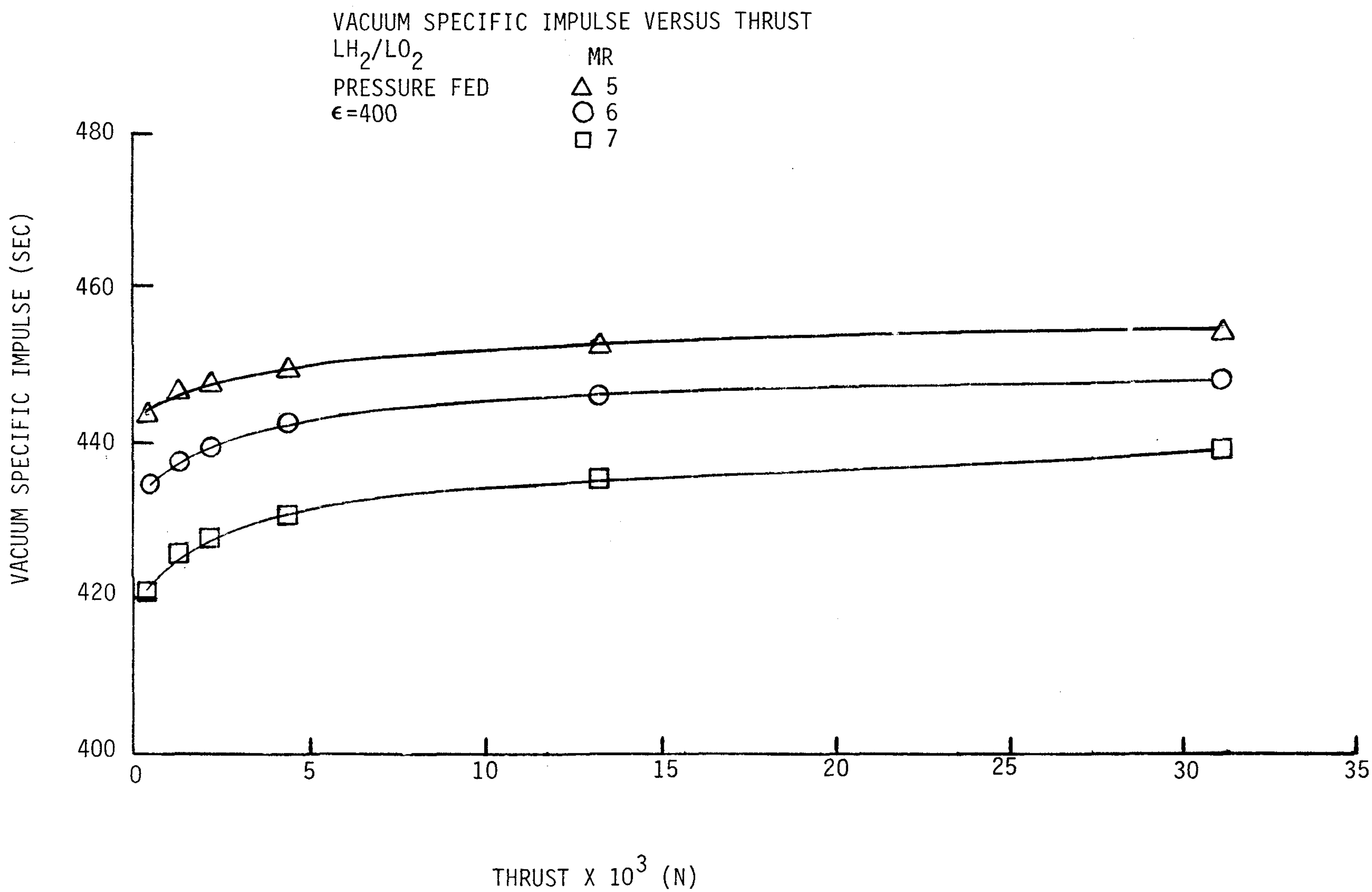
ENGINE RETRACTED LENGTH VERSUS THRUST
RP-1/LO_2
PUMP FED
ϵ=400
FOR MR OF 2.8, 3.0, & 3.2
ENGINE RETRACTED LENGTH (CM)
140
120
100
80
60
40
20
0
0
5
10
15
20
25
30
35
THRUST X 10^3 (N)

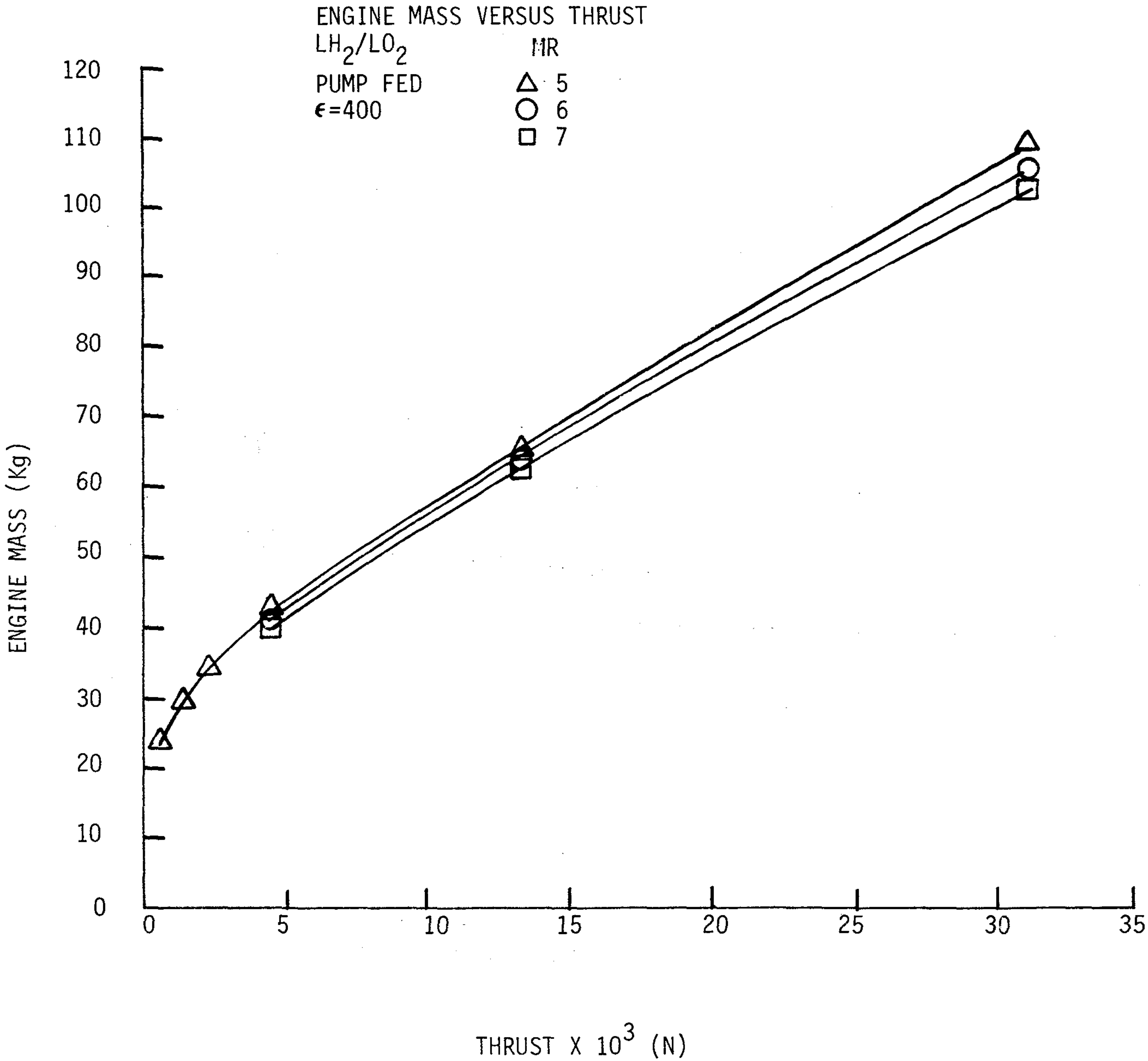

VACUUM SPECIFIC IMPULSE VERSUS THRUST
RP-1/LO2 MR △ 2.8
PUMP FED ○ 3.0
ϵ=400 □ 3.2
VACUUM SPECIFIC IMPULSE (SEC)
360
350
340
330
320
0
5
10
15
20
25
30
35
THRUST X 10^3 (N)



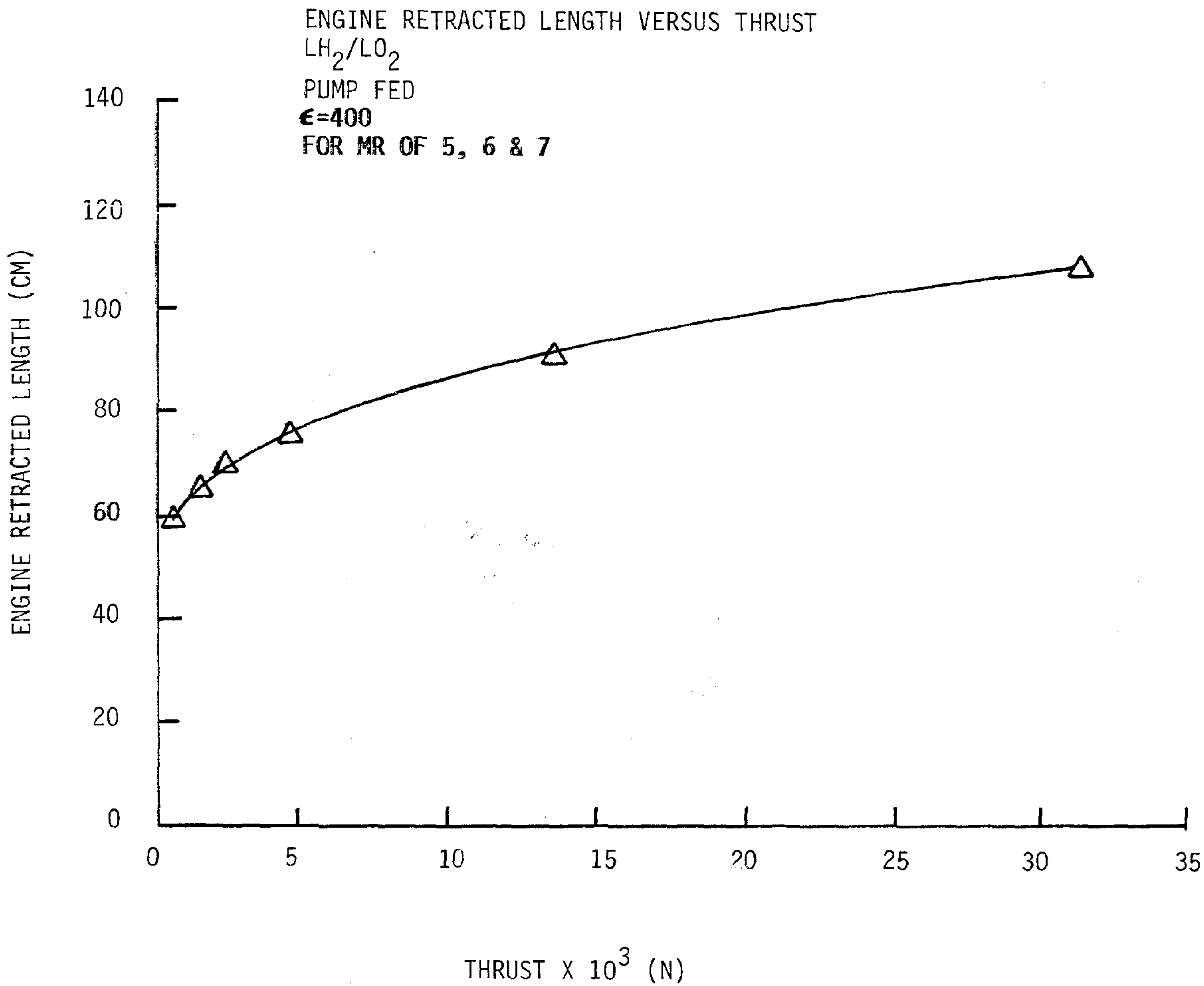
ENGINE MASS VERSUS THRUST
LH2/LO2
PRESSURE FED
ϵ=400
MR
5
6
7
ENGINE MASS (Kg)
300
250
200
150
100
50
0
0
5
10
15
20
25
30
35
THRUST X 10^3 (N)

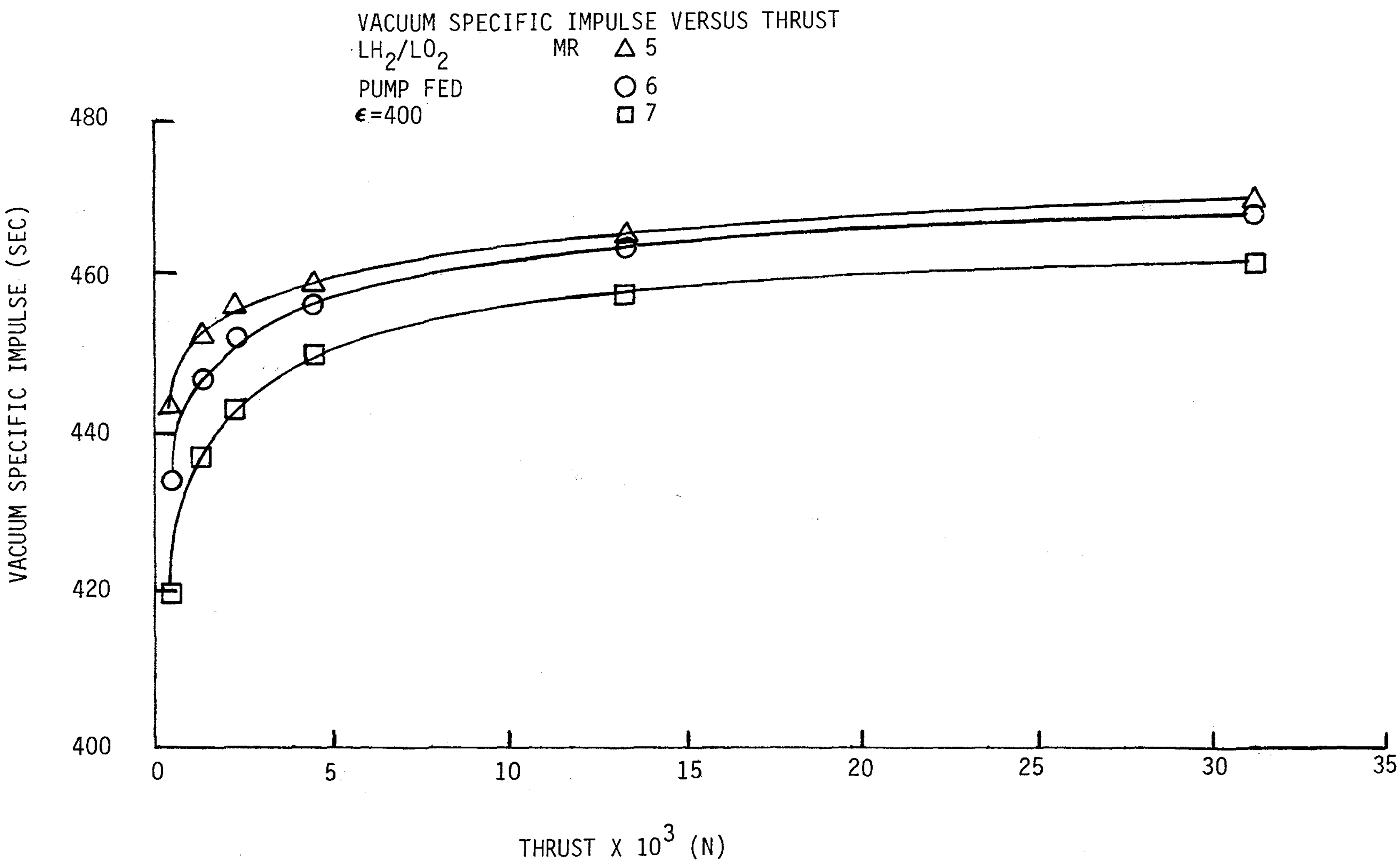

ENGINE RETRACTED LENGTH VERSUS THRUST
LH_2/LO_2
PRESSURE FED
ϵ=400
MR
5
6
7
ENGINE RETRACTED LENGTH (CM)
THRUST X 10^3 (N)
0
50
100
150
200
250
300
350
0
5
10
15
20
25
30
35

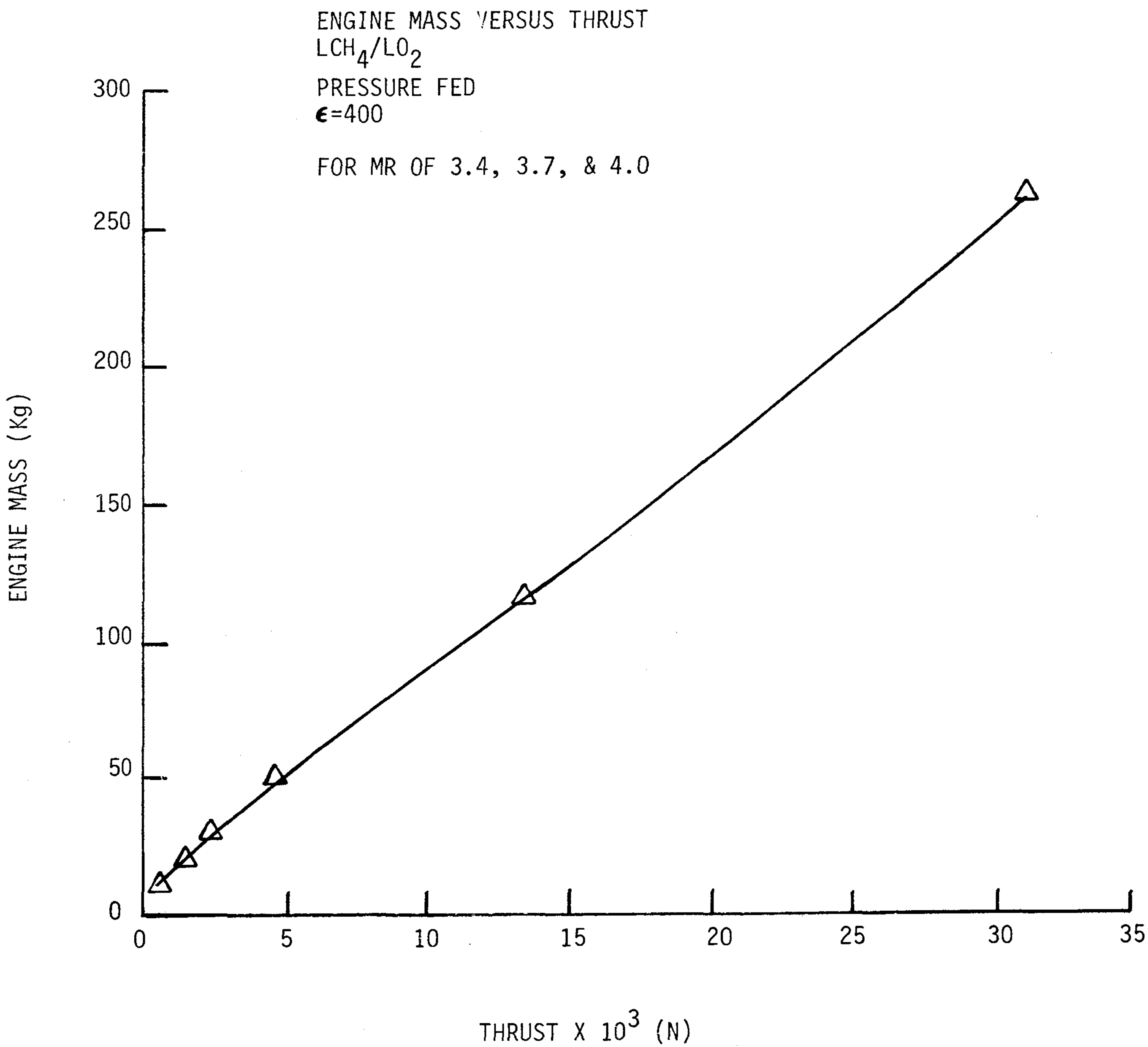

VACUUM SPECIFIC IMPULSE VERSUS THRUST
LH2/LO2
PRESSURE FED
ϵ=400
MR
5
6
7
VACUUM SPECIFIC IMPULSE (SEC)
480
460
440
420
400
0
5
10
15
20
25
30
35
THRUST X 10^3 (N)

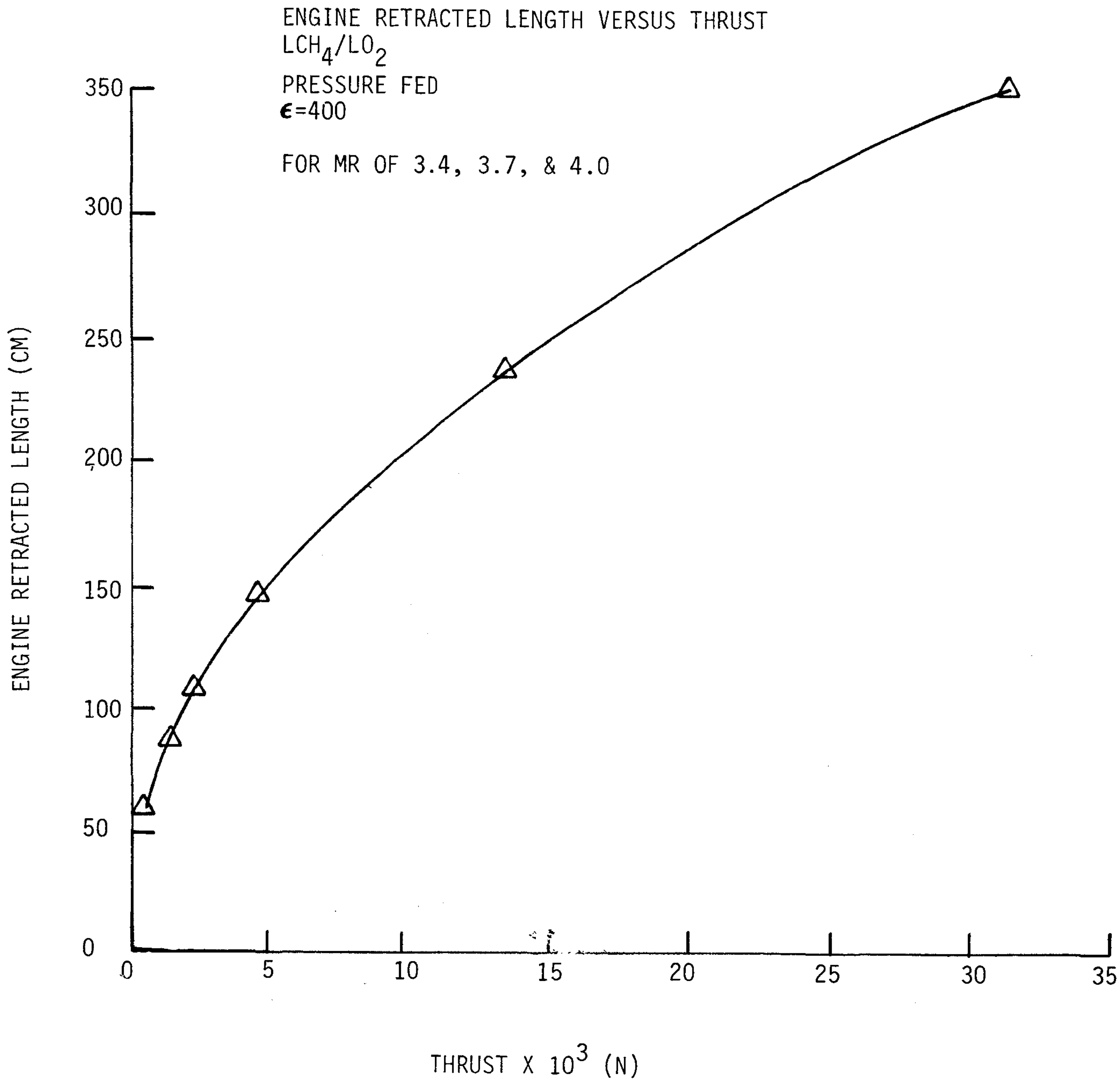


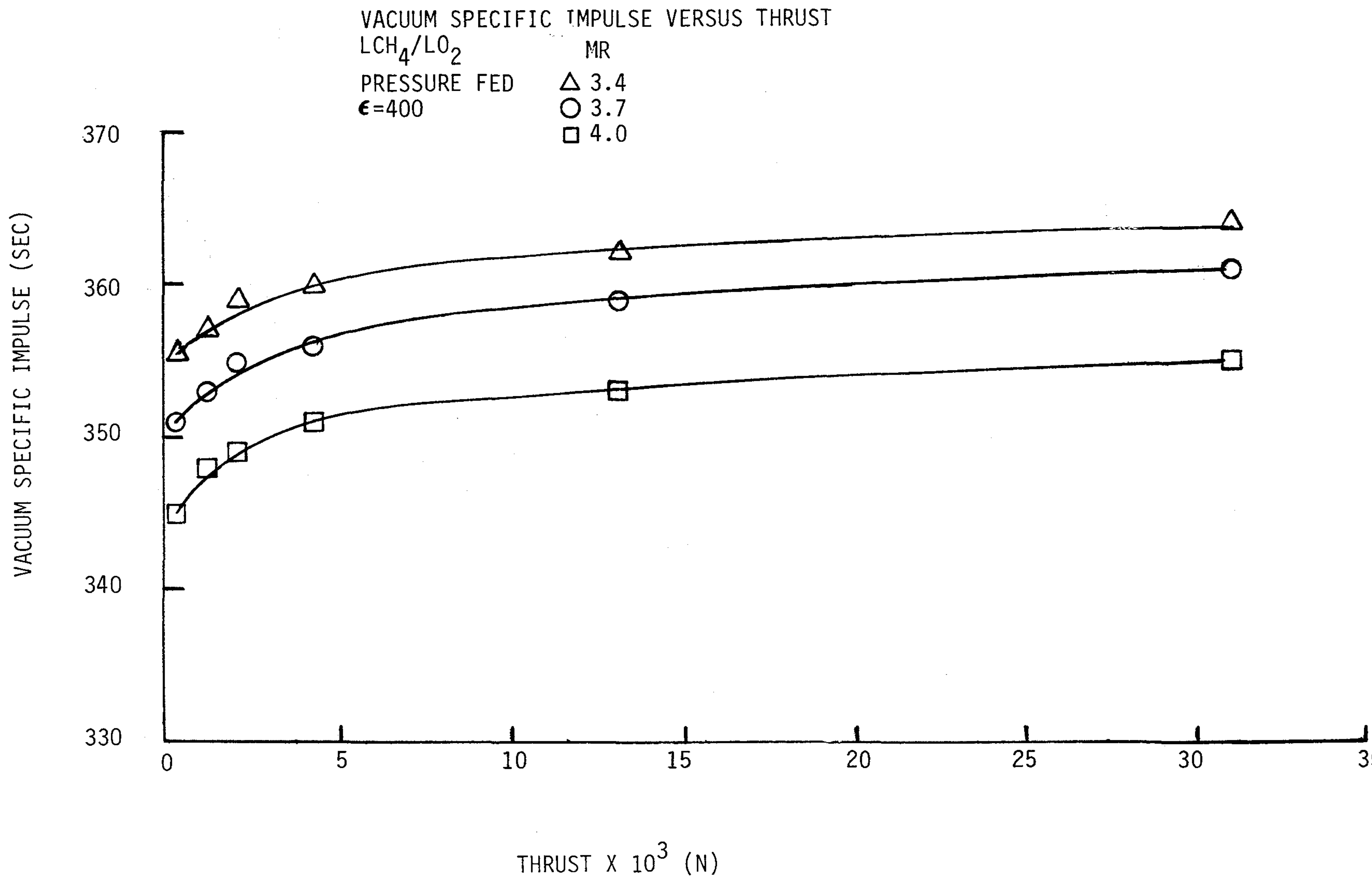
ENGINE MASS VERSUS THRUST
LH2/LO2
PUMP FED
ϵ=400
MR
5
6
7
ENGINE MASS (Kg)
120
110
100
90
80
70
60
50
40
30
20
10
0
0
5
10
15
20
25
30
35
THRUST X 10^3 (N)

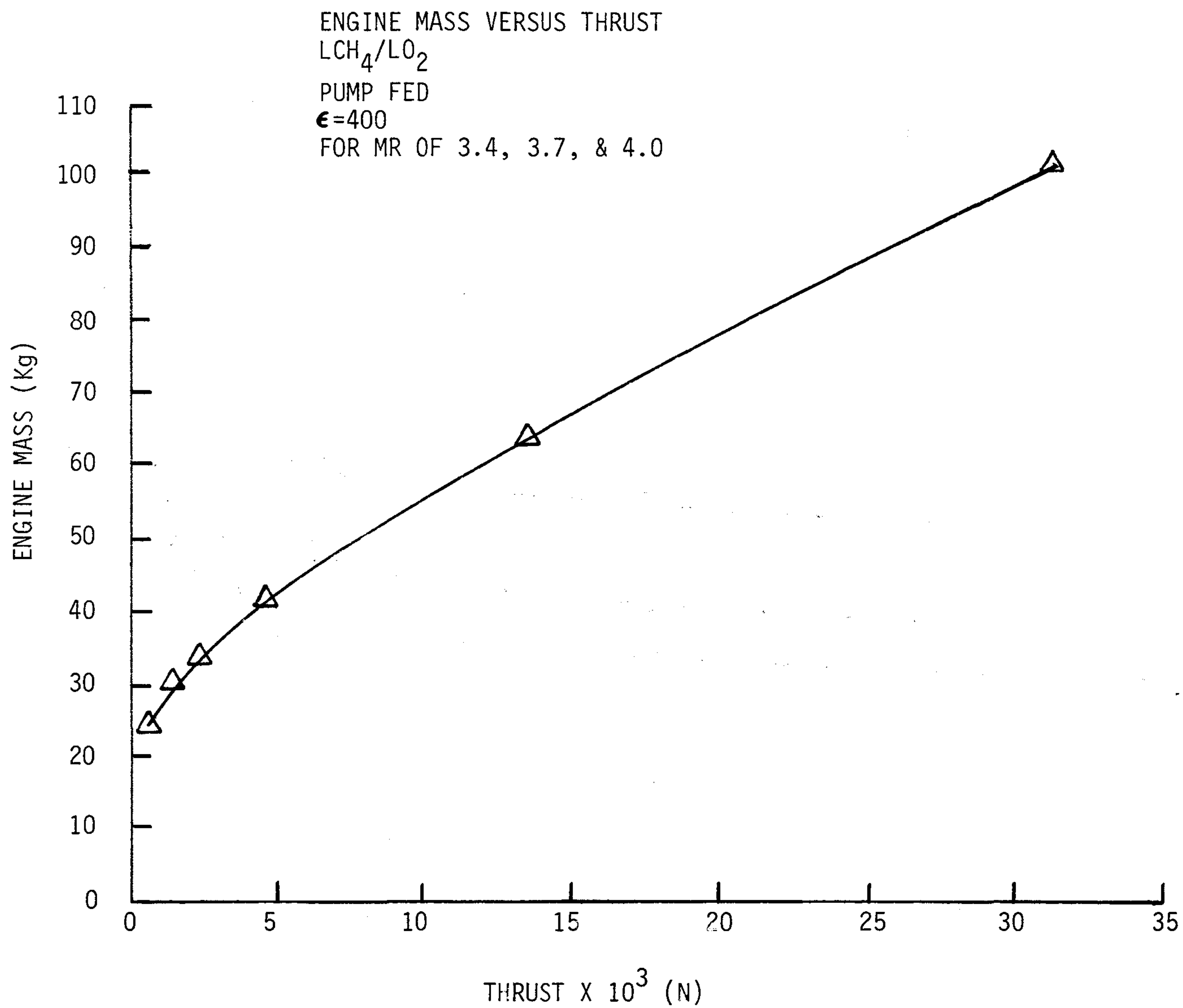

ENGINE RETRACTED LENGTH VERSUS THRUST
LH_2/LO_2
PUMP FED
ϵ=400
FOR MR OF 5, 6 & 7
ENGINE RETRACTED LENGTH (CM)
0
20
40
60
80
100
120
140
0
5
10
15
20
25
30
35
THRUST X 10^3 (N)

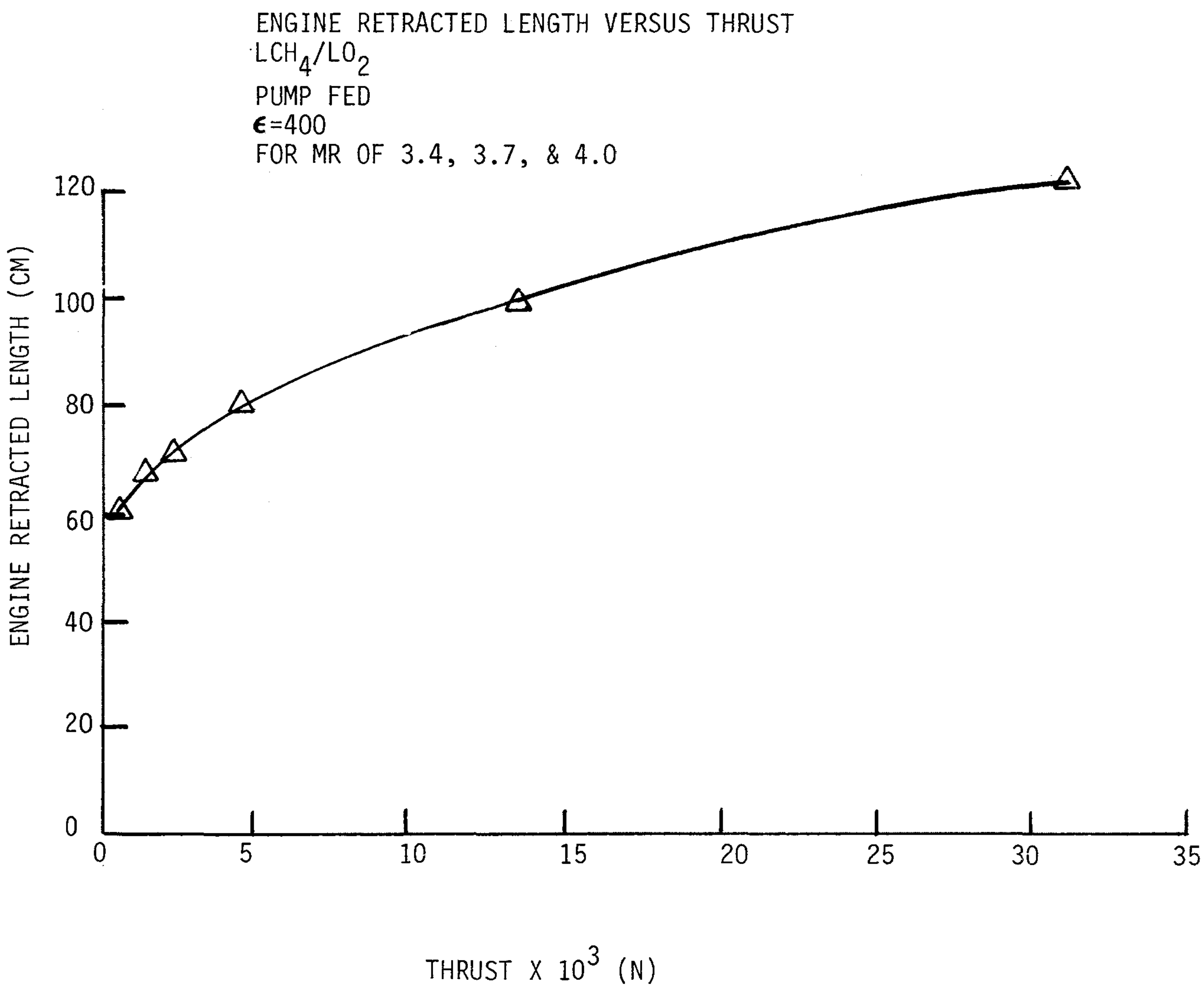

VACUUM SPECIFIC IMPULSE VERSUS THRUST
LH_2/LO_2
PUMP FED
ϵ=400
MR △ 5
○ 6
□ 7
VACUUM SPECIFIC IMPULSE (SEC)
480
460
440
420
400
0
5
10
15
20
25
30
35
THRUST X 10^3 (N)


ENGINE MASS VERSUS THRUST
LCH_4/LO_2
PRESSURE FED
ϵ=400
FOR MR OF 3.4, 3.7, & 4.0
ENGINE MASS (Kg)
300
250
200
150
100
50
0
0
5
10
15
20
25
30
35
THRUST X 10^3 (N)

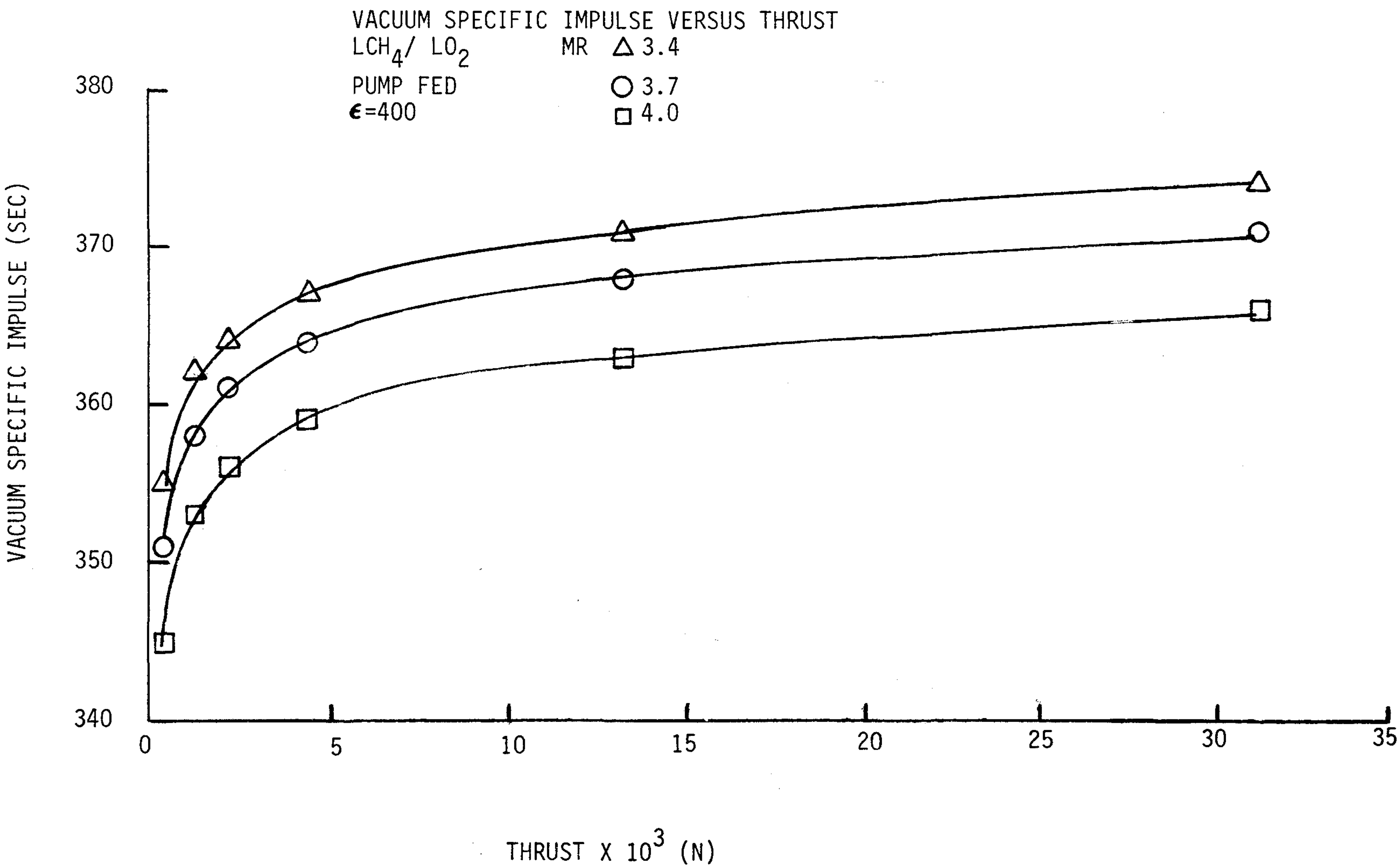

ENGINE RETRACTED LENGTH VERSUS THRUST
LCH_4/LO_2
PRESSURE FED
$\epsilon=400$
FOR MR OF 3.4, 3.7, & 4.0
ENGINE RETRACTED LENGTH (CM)
350
300
250
200
150
100
50
0
0
5
10
15
20
25
30
35
THRUST X 10^3 (N)


VACUUM SPECIFIC IMPULSE VERSUS THRUST
LCH4/LO2
PRESSURE FED
ε=400
MR
3.4
3.7
4.0
VACUUM SPECIFIC IMPULSE (SEC)
370
360
350
340
330
0
5
10
15
20
25
30
35
THRUST X 10^3 (N)


ENGINE MASS VERSUS THRUST
LCH4/LO2
PUMP FED
ε=400
FOR MR OF 3.4, 3.7, & 4.0
ENGINE MASS (Kg)
0
10
20
30
40
50
60
70
80
90
100
110
THRUST X 10^3 (N)
0
5
10
15
20
25
30
35



ENGINE RETRACTED LENGTH VERSUS THRUST
LCH4/LO2
PUMP FED
ε=400
FOR MR OF 3.4, 3.7, & 4.0
ENGINE RETRACTED LENGTH (CM)
120
100
80
60
40
20
0
0
5
10
15
20
25
30
35
THRUST X 10^3 (N)


VACUUM SPECIFIC IMPULSE VERSUS THRUST
LCH_4/LO_2
PUMP FED
ϵ=400
MR △ 3.4
○ 3.7
□ 4.0
VACUUM SPECIFIC IMPULSE (SEC)
380
370
360
350
340
0
5
10
15
20
25
30
35
THRUST X 10^3 (N)

APPENDIX B

MASS STATEMENTS (PROP OUTPUT SHEETS)

The mass statements for the various propulsion system configurations, analyzed in Section V, are displayed in the following pages. These statements were used to determine available payload mass and length, and center of gravity. The statements are arranged by orbit transfer strategy in the order of 8 perigee burn - constant acceleration; 1 perigee burn - constant acceleration; and 8 perigee burn - constant thrust. Each orbit transfer strategy section is further divided into the four propellant combinations: N_2O_4/MMH, LO_2/RP-1, LO_2/LCH_4, and LO_2/LH_2. The structure of each propellant combination section, if applicable*, is shown below.

Propellant Combination "A"

- Pressure Fed Engine
  - Maximum Performance Configuration
    - Thrust-To-Mass Ratio
      - Mixture Ratio
  - Minimum Length Configuration
    - Thrust-To-Mass Ratio
      - Mixture Ratio
- Pump Fed Engine
  - Maximum Performance Configuration
    - Thrust-To-Mass Ratio
      - Mixture Ratio
  - Minimum Length Configuration
    - Thrust-To-Mass Ratio
      - Mixture Ratio

*Thrust-to-mass ratios of 0.01, 0.015, 0.05 and 0.10 were not analyzed for all cases.

9 BURNS, CONSTANT ACCELERATION, T/M=0.01

N2O4/MMH, MAX. PERF., PRESSURE FED, MR = 1.8

VEHICLE MASS =27215.5 KG DELTA V= 4815.8 M/S AVE. ISP=3167.4 N-S/KG

```
TOTAL PROPELLANT                                21916.91 KG
  USABLE FUEL                       7594.78
  USABLE OXIDIZER                  13670.61
  FUEL TRAPPED                       228.20
  OXID TRAPPED                       409.72
  FUEL START-S/D LOSSES                6.80
  OXID START-S/D LOSSES                6.80

OXIDIZER TANKS (NO.= 1)                            289.23
 (ELLIPSOIDAL)
  DIAMETER=     3.032 M
  LENGTH  =     2.144 M
  VOLUME  =    10.315 M3
  AVG THK =    .00343 M
  FS = 1.50,  FNOP= 1.30

FUEL TANKS (NO.= 1)                                299.12
 (ELLIPSOIDAL)
  DIAMETER=     2.944 M
  LENGTH  =     2.082 M
  VOLUME  =     9.448 M3
  AVG THK =    .00376 M
  FS = 1.50,  FNOP= 1.30

PRESSURANT                                          44.225

PRESSURANT TANKS (NO.= 1)                          234.63
  DIA=    1.2596 M
  VOL=     1.047 M3
  THK=    .01063 M
  FS = 1.50,  FNOP= 1.10

ENGINES (NO.= 1)                                    37.19

COMPONENTS AND LINES                               363.33
ENG. MOUNTS,SUPPORTS                               949.37

TOTAL WET SYSTEM MASS                            24134.0
TOTAL BURNOUT MASS                                2855.0
   (INCL.NON-USABLE PROP. AND GAS)

MASS FRACTION                                        .881
TOTAL IMPULSE                               67359105.6 N-S

             PRESSURE SCHEDULE(N/M2  )  AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =  .2482E+08   INITIAL CHAMBER PRESSURE =0.
INITIAL OX SYS PRESSURE   =  .1069E+07   FINAL OX SYS PRESSURE    =  .1069E+07
INITIAL FU SYS PRESSURE   =  .1207E+07   FINAL FU SYS PRESSURE    =  .1207E+07
```

9 BURNS, CONSTANT ACCELERATION, T/M=0.01

N2O4/MMH, MAX. PERF., PRESSURE FED, MR = 2.2

VEHICLE MASS =27215.5 KG DELTA V= 4815.8 M/S AVE. ISP=3153.7 N-S/KG

TOTAL PROPELLANT		21955.52 KG
USABLE FUEL	6657.70	
USABLE OXIDIZER	14646.94	
FUEL TRAPPED	200.31	
OXID TRAPPED	436.96	
FUEL START-S/D LOSSES	6.80	
OXID START-S/D LOSSES	6.80	
OXIDIZER TANKS (NO.= 1)		309.84
(ELLIPSOIDAL)		
DIAMETER= 3.102 M		
LENGTH = 2.193 M		
VOLUME = 11.050 M3		
AVG THK = .00351 M		
FS = 1.50, FNOP= 1.30		
FUEL TANKS (NO.= 1)		262.25
(ELLIPSOIDAL)		
DIAMETER= 2.818 M		
LENGTH = 1.993 M		
VOLUME = 8.284 M3		
AVG THK = .00360 M		
FS = 1.50, FNOP= 1.30		
PRESSURANT		43.266
PRESSURANT TANKS (NO.= 1)		229.61
DIA= 1.2506 M		
VOL= 1.024 M3		
THK= .01055 M		
FS = 1.50, FNOP= 1.10		
ENGINES (NO.= 1)		37.19
COMPONENTS AND LINES		363.33
ENG. MOUNTS,SUPPORTS		949.37
TOTAL WET SYSTEM MASS		24150.4
TOTAL BURNOUT MASS		2832.1
(INCL.NON-USABLE PROP. AND GAS)		
MASS FRACTION		.882
TOTAL IMPULSE		67190937.9 N-S

PRESSURE SCHEDULE(N/M2) AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =	.2482E+08	INITIAL CHAMBER PRESSURE =	0.
INITIAL OX SYS PRESSURE =	.1069E+07	FINAL OX SYS PRESSURE =	.1069E+07
INITIAL FU SYS PRESSURE =	.1207E+07	FINAL FU SYS PRESSURE =	.1207E+07

9 BURNS, CONSTANT ACCELERATION,T/M=0.01

N2O4/MMH, MAX. PERF., PRESSURE FED, MR = 2.6

VEHICLE MASS =27215.5 KG DELTA V= 4815.8 M/S AVE. ISP=3075.2 N-S/KG

TOTAL PROPELLANT		22188.08 KG
USABLE FUEL	5980.68	
USABLE OXIDIZER	15549.78	
FUEL TRAPPED	178.91	
OXID TRAPPED	465.09	
FUEL START-S/D LOSSES	6.80	
OXID START-S/D LOSSES	6.80	
OXIDIZER TANKS (NO.= 1)		328.95
(ELLIPSOIDAL)		
DIAMETER= 3.164 M		
LENGTH = 2.238 M		
VOLUME = 11.732 M3		
AVG THK = .00358 M		
FS = 1.50, FNOP= 1.30		
FUEL TANKS (NO.= 1)		235.57
(ELLIPSOIDAL)		
DIAMETER= 2.719 M		
LENGTH = 1.923 M		
VOLUME = 7.441 M3		
AVG THK = .00347 M		
FS = 1.50, FNOP= 1.30		
PRESSURANT		42.907
PRESSURANT TANKS (NO.= 1)		227.75
DIA= 1.2472 M		
VOL= 1.016 M3		
THK= .01052 M		
FS = 1.50, FNOP= 1.10		
ENGINES (NO.= 1)		37.19
COMPONENTS AND LINES		363.33
ENG. MOUNTS,SUPPORTS		949.37
TOTAL WET SYSTEM MASS		24373.2
TOTAL BURNOUT MASS		2829.1
(INCL.NON-USABLE PROP. AND GAS)		
MASS FRACTION		.883
TOTAL IMPULSE		66214016.7 N-S

PRESSURE SCHEDULE(N/M2) AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =	.2482E+08	INITIAL CHAMBER PRESSURE =	0.
INITIAL OX SYS PRESSURE =	.1069E+07	FINAL OX SYS PRESSURE =	.1069E+07
INITIAL FU SYS PRESSURE =	.1207E+07	FINAL FU SYS PRESSURE =	.1207E+07

9 BURNS, CONSTANT ACCELERATION, T/M=0.015

N2O4/MMH, MAX. PERF., PRESSURE FED, MR = 1.8

VEHICLE MASS =27215.5 KG DELTA V= 4480.6 M/S AVE. ISP=3176.2 N-S/KG

TOTAL PROPELLANT		21195.03 KG
USABLE FUEL	7348.21	
USABLE OXIDIZER	13226.77	
FUEL TRAPPED	216.52	
OXID TRAPPED	389.01	
FUEL START-S/D LOSSES	7.26	
OXID START-S/D LOSSES	7.26	
OXIDIZER TANKS (NO.= 1) (ELLIPSOIDAL)		279.71
DIAMETER= 2.998 M		
LENGTH = 2.120 M		
VOLUME = 9.975 M3		
AVG THK = .00339 M		
FS = 1.50, FNOP= 1.30		
FUEL TANKS (NO.= 1) (ELLIPSOIDAL)		289.27
DIAMETER= 2.911 M		
LENGTH = 2.059 M		
VOLUME = 9.137 M3		
AVG THK = .00372 M		
FS = 1.50, FNOP= 1.30		
PRESSURANT		42.790
PRESSURANT TANKS (NO.= 1)		227.03
DIA= 1.2459 M		
VOL= 1.013 M3		
THK= .01051 M		
FS = 1.50, FNOP= 1.10		
ENGINES (NO.= 1)		49.90
COMPONENTS AND LINES		363.33
ENG. MOUNTS,SUPPORTS		944.83
TOTAL WET SYSTEM MASS		23391.9
TOTAL BURNOUT MASS (INCL.NON-USABLE PROP. AND GAS)		2802.4
MASS FRACTION		.880
TOTAL IMPULSE		65353809.2 N-S

PRESSURE SCHEDULE(N/M2) AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =	.2482E+08	INITIAL CHAMBER PRESSURE =	0.
INITIAL OX SYS PRESSURE =	.1069E+07	FINAL OX SYS PRESSURE =	.1069E+07
INITIAL FU SYS PRESSURE =	.1207E+07	FINAL FU SYS PRESSURE =	.1207E+07

9 BURNS, CONSTANT ACCELERATION, T/M=0.015

N204/MMH, MAX. PERF., PRESSURE FED, MR = 2.2

VEHICLE MASS =27215.5 KG DELTA V= 4480.6 M/S AVE. ISP=3162.5 N-S/KG

TOTAL PROPELLANT		21237.22 KG
USABLE FUEL	6442.35	
USABLE OXIDIZER	14173.17	
FUEL TRAPPED	190.32	
OXID TRAPPED	416.87	
FUEL START-S/D LOSSES	7.26	
OXID START-S/D LOSSES	7.26	
OXIDIZER TANKS (NO.= 1)		299.71
(ELLIPSOIDAL)		
DIAMETER= 3.068 M		
LENGTH = 2.169 M		
VOLUME = 10.689 M3		
AVG THK = .00347 M		
FS = 1.50, FNOP= 1.30		
FUEL TANKS (NO.= 1)		253.66
(ELLIPSOIDAL)		
DIAMETER= 2.787 M		
LENGTH = 1.971 M		
VOLUME = 8.013 M3		
AVG THK = .00356 M		
FS = 1.50, FNOP= 1.30		
PRESSURANT		41.868
PRESSURANT TANKS (NO.= 1)		222.19
DIA= 1.2370 M		
VOL= .991 M3		
THK= .01044 M		
FS = 1.50, FNOP= 1.10		
ENGINES (NO.= 1)		49.90
COMPONENTS AND LINES		363.33
ENG. MOUNTS,SUPPORTS		944.83
TOTAL WET SYSTEM MASS		23412.7
TOTAL BURNOUT MASS		2782.7
(INCL.NON-USABLE PROP. AND GAS)		
MASS FRACTION		.881
TOTAL IMPULSE		65199540.1 N-S

PRESSURE SCHEDULE(N/M2) AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =	.2482E+08	INITIAL CHAMBER PRESSURE =	0.
INITIAL OX SYS PRESSURE =	.1069E+07	FINAL OX SYS PRESSURE =	.1069E+07
INITIAL FU SYS PRESSURE =	.1207E+07	FINAL FU SYS PRESSURE =	.1207E+07

9 BURNS, CONSTANT ACCELERATION, T/M=0.015

N204/MMH, MAX. PERF., PRESSURE FED, MR = 2.6

VEHICLE MASS =27215.5 KG DELTA V= 4480.6 M/S AVE. ISP=3088.0 N-S/KG

TOTAL PROPELLANT		21464.80 KG
USABLE FUEL	5788.16	
USABLE OXIDIZER	15049.21	
FUEL TRAPPED	170.86	
OXID TRAPPED	442.05	
FUEL START-S/D LOSSES	7.26	
OXID START-S/D LOSSES	7.26	
OXIDIZER TANKS (NO.= 1)		318.21
(ELLIPSOIDAL)		
DIAMETER= 3.130 M		
LENGTH = 2.213 M		
VOLUME = 11.348 M3		
AVG THK = .00354 M		
FS = 1.50, FNOP= 1.30		
FUEL TANKS (NO.= 1)		227.93
(ELLIPSOIDAL)		
DIAMETER= 2.689 M		
LENGTH = 1.901 M		
VOLUME = 7.200 M3		
AVG THK = .00344 M		
FS = 1.50, FNOP= 1.30		
PRESSURANT		41.527
PRESSURANT TANKS (NO.= 1)		220.43
DIA= 1.2337 M		
VOL= .983 M3		
THK= .01041 M		
FS = 1.50, FNOP= 1.10		
ENGINES (NO.= 1)		43.90
COMPONENTS AND LINES		363.33
ENG. MOUNTS,SUPPORTS		944.83
TOTAL WET SYSTEM MASS		23631.0
TOTAL BURNOUT MASS		2779.1
(INCL.NON-USABLE PROP. AND GAS)		
MASS FRACTION		.882
TOTAL IMPULSE		64348162.0 N-S

PRESSURE SCHEDULE(N/M2) AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =	.2482E+08	INITIAL CHAMBER PRESSURE =	0.
INITIAL OX SYS PRESSURE =	.1069E+07	FINAL OX SYS PRESSURE =	.1069E+07
INITIAL FU SYS PRESSURE =	.1207E+07	FINAL FU SYS PRESSURE =	.1207E+07

9 BURNS, CONSTANT ACCELERATION, T/M=0.1

N2O4/MMH, MAX. PERF., PRESSURE FED, MR = 1.8

```
VEHICLE MASS  =27215.5 KG    DELTA V=  4291.6 M/S   AVE. ISP=3229.2 N-S/KG

TOTAL PROPELLANT                             20628.18 KG
  USABLE FUEL                     7146.44
  USABLE OXIDIZER                12863.59
  FUEL TRAPPED                     210.11
  OXID TRAPPED                     377.20
  FUEL START-S/D LOSSES             15.42
  OXID START-S/D LOSSES             15.42

OXIDIZER TANKS (NO.= 1)                        272.17
 (ELLIPSOIDAL)
  DIAMETER=     2.971 M
  LENGTH   =    2.101 M
  VOLUME   =    9.707 M3
  AVG THK  =   .00336 M
  FS = 1.50,  FNOP= 1.30

FUEL TANKS (NO.= 1)                            281.63
 (ELLIPSOIDAL)
  DIAMETER=     2.886 M
  LENGTH   =    2.040 M
  VOLUME   =    8.896 M3
  AVG THK  =   .00369 M
  FS = 1.50,  FNOP= 1.30

PRESSURANT                                     41.642

PRESSURANT TANKS (NO.= 1)                      220.93
  DIA=    1.2346 M
  VOL=      .985 M3
  THK=    .01042 M
  FS = 1.50,  FNOP= 1.10


ENGINES (NO.= 1)                               232.24

COMPONENTS AND LINES                           363.33
ENG. MOUNTS,SUPPORTS                           941.66

TOTAL WET SYSTEM MASS                         22981.8
TOTAL BURNOUT MASS                             2940.9
   (INCL.NON-USABLE PROP. AND GAS)

MASS FRACTION                                    .871
TOTAL IMPULSE                             64618954.6 N-S

             PRESSURE SCHEDULE(N/M2  )   AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =   .2482E+08   INITIAL CHAMBER PRESSURE =0.
INITIAL OX SYS PRESSURE   =   .1069E+07   FINAL OX SYS PRESSURE    =  .1069E+07
INITIAL FU SYS PRESSURE   =   .1207E+07   FINAL FU SYS PRESSURE    =  .1207E+07
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9 BURNS, CONSTANT ACCELERATION, T/M=0.1

N204/MMH, MAX. PERF., PRESSURE FED, MR = 2.2

VEHICLE MASS =27215.5 KG DELTA V= 4291.6 M/S AVE. ISP=3208.6 N-S/KG

TOTAL PROPELLANT		20691.10 KG
USABLE FUEL	6272.26	
USABLE OXIDIZER	13798.97	
FUEL TRAPPED	184.70	
OXID TRAPPED	404.33	
FUEL START-S/D LOSSES	15.42	
OXID START-S/D LOSSES	15.42	
OXIDIZER TANKS (NO.= 1)		291.94
(ELLIPSOIDAL)		
DIAMETER= 3.041 M		
LENGTH = 2.150 M		
VOLUME = 10.411 M3		
AVG THK = .00344 M		
FS = 1.50, FNOP= 1.30		
FUEL TANKS (NO.= 1)		247.26
(ELLIPSOIDAL)		
DIAMETER= 2.763 M		
LENGTH = 1.954 M		
VOLUME = 7.810 M3		
AVG THK = .00353 M		
FS = 1.50, FNOP= 1.30		
PRESSURANT		40.790
PRESSURANT TANKS (NO.= 1)		216.47
DIA= 1.2263 M		
VOL= .965 M3		
THK= .01035 M		
FS = 1.50, FNOP= 1.10		
ENGINES (NO.= 1)		232.24
COMPONENTS AND LINES		363.33
ENG. MOUNTS,SUPPORTS		941.66
TOTAL WET SYSTEM MASS		23024.8
TOTAL BURNOUT MASS		2922.7
(INCL.NON-USABLE PROP. AND GAS)		
MASS FRACTION		.872
TOTAL IMPULSE		64403232.0 N-S

PRESSURE SCHEDULE(N/M2) AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =	.2482E+08	INITIAL CHAMBER PRESSURE =	0.
INITIAL OX SYS PRESSURE =	.1069E+07	FINAL OX SYS PRESSURE =	.1069E+07
INITIAL FU SYS PRESSURE =	.1207E+07	FINAL FU SYS PRESSURE =	.1207E+07

9 BURNS, CONSTANT ACCELERATION, T/W=0.1

N2O4/MMH, MAX. PERF., PRESSURE FED, MR = 2.6

VEHICLE MASS =27215.5 KG DELTA V= 4291.6 M/S AVE. ISP=3140.9 N-S/KG

TOTAL PROPELLANT		20899.25 KG
USABLE FUEL	5631.70	
USABLE OXIDIZER	14642.43	
FUEL TRAPPED	165.58	
OXID TRAPPED	428.69	
FUEL START-S/D LOSSES	15.42	
OXID START-S/D LOSSES	15.42	
OXIDIZER TANKS (NO.= 1)		309.75
(ELLIPSOIDAL)		
DIAMETER= 3.102 M		
LENGTH = 2.193 M		
VOLUME = 11.047 M3		
AVG THK = .00351 M		
FS = 1.50, FNOP= 1.30		
FUEL TANKS (NO.= 1)		222.06
(ELLIPSOIDAL)		
DIAMETER= 2.666 M		
LENGTH = 1.885 M		
VOLUME = 7.014 M3		
AVG THK = .00341 M		
FS = 1.50, FNOP= 1.30		
PRESSURANT		40.432
PRESSURANT TANKS (NO.= 1)		214.61
DIA= 1.2227 M		
VOL= .957 M3		
THK= .01032 M		
FS = 1.50, FNOP= 1.10		
ENGINES (NO.= 1)		232.24
COMPONENTS AND LINES		363.33
ENG. MOUNTS, SUPPORTS		941.66
TOTAL WET SYSTEM MASS		23223.3
TOTAL BURNOUT MASS		2918.4
(INCL.NON-USABLE PROP. AND GAS)		
MASS FRACTION		.873
TOTAL IMPULSE		63682438.5 N-S

PRESSURE SCHEDULE(N/M2) AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =	.2482E+08	INITIAL CHAMBER PRESSURE =	0.
INITIAL OX SYS PRESSURE =	.1069E+07	FINAL OX SYS PRESSURE =	.1069E+07
INITIAL FU SYS PRESSURE =	.1207E+07	FINAL FU SYS PRESSURE =	.1207E+07

9 BURNS, CONSTANT ACCELERATION, T/M=0.01

N2O4/MMH, MIN. LENGTH, PRESSURE FED, MR = 1.8

VEHICLE MASS =27215.5 KG DELTA V= 4815.8 M/S AVE. ISP=3167.4 N-S/KG

```
TOTAL PROPELLANT                              21921.02 KG
  USABLE FUEL                      7594.78
  USABLE OXIDIZER                 13670.61
  FUEL TRAPPED                      229.56
  OXID TRAPPED                      412.46
  FUEL START-S/D LOSSES               6.80
  OXID START-S/D LOSSES               6.80

OXIDIZER TANKS (NO.= 1)                         300.98
 (TOROIDAL)
  INNER DIA=     1.947 M
  OUTER DIA=     4.267 M
  HEIGHT   =     1.160 M
  VOLUME   =    10.317 M3
  AVG THK  =    .00235 M
  FS = 1.50,  FNOP= 1.30

FUEL TANKS (NO.= 1)                             299.17
 (ELLIPSOIDAL)
  DIAMETER=     2.944 M
  LENGTH  =     2.082 M
  VOLUME  =     9.450 M3
  AVG THK =    .00376 M
  FS = 1.50,  FNOP= 1.30

PRESSURANT                                      44.225

PRESSURANT TANKS (NO.= 1)                       234.63
  DIA=    1.2596 M
  VOL=     1.047 M3
  THK=    .01063 M
  FS = 1.50,  FNOP= 1.10


ENGINES (NO.= 1)                                 37.19

COMPONENTS AND LINES                            386.01
ENG. MOUNTS,SUPPORTS                            949.37

TOTAL WET SYSTEM MASS                          24172.6
TOTAL BURNOUT MASS                              2893.6
   (INCL.NON-USABLE PROP. AND GAS)

MASS FRACTION                                     .880
TOTAL IMPULSE                             67359105.6 N-S

             PRESSURE SCHEDULE(N/M2  )   AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =  .2482E+08   INITIAL CHAMBER PRESSURE =0.
INITIAL OX SYS PRESSURE   =  .1069E+07   FINAL OX SYS PRESSURE   =  .1069E+07
INITIAL FU SYS PRESSURE   =  .1207E+07   FINAL FU SYS PRESSURE   =  .1207E+07
```

9 BURNS, CONSTANT ACCELERATION, T/M=0.01

```
  N2O4/MMH, MIN. LENGTH, PRESSURE FED,              MR = 2.2

VEHICLE MASS  =27215.5 KG     DELTA V=  4815.8 M/S   AVE. ISP=3153.7 N-S/KG

TOTAL PROPELLANT                           21961.44 KG
  USABLE FUEL                     6657.70
  USABLE OXIDIZER                14646.94
  FUEL TRAPPED                     201.67
  OXID TRAPPED                     441.52
  FUEL START-S/D LOSSES              6.80
  OXID START-S/D LOSSES              6.80

OXIDIZER TANKS (NO.= 1)                      326.05
 (TOROIDAL)
  INNER DIA=     1.846 M
  OUTER DIA=     4.267 M
  HEIGHT   =     1.211 M
  VOLUME   =    11.053 M3
  AVG THK  =    .00248 M
  FS = 1.50,  FNOP= 1.30

FUEL TANKS (NO.= 1)                          262.31
 (ELLIPSOIDAL)
  DIAMETER=     2.818 M
  LENGTH  =     1.993 M
  VOLUME  =     8.286 M3
  AVG THK =    .00360 M
  FS = 1.50,  FNOP= 1.30

PRESSURANT                                    43.267

PRESSURANT TANKS (NO.= 1)                    229.61
  DIA=    1.2506 M
  VOL=     1.024 M3
  THK=    .01055 M
  FS = 1.50,  FNOP= 1.10


ENGINES (NO.= 1)                              37.19

COMPONENTS AND LINES                         386.01
ENG. MOUNTS,SUPPORTS                         949.37

TOTAL WET SYSTEM MASS                       24195.2
TOTAL BURNOUT MASS                           2877.0
   (INCL.NON-USABLE PROP. AND GAS)

MASS FRACTION                                  .881
TOTAL IMPULSE                           67190937.9 N-S

             PRESSURE SCHEDULE(N/M2  )   AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =   .2482E+08    INITIAL CHAMBER PRESSURE =0.
INITIAL OX SYS PRESSURE   =   .1069E+07    FINAL OX SYS PRESSURE    =  .1069E+07
INITIAL FU SYS PRESSURE   =   .1207E+07    FINAL FU SYS PRESSURE    =  .1207E+07
```

9 BURNS, CONSTANT ACCELERATION, T/M=0.01

```
    N2O4/MMH, MIN. LENGTH, PRESSURE FED,              MR = 2.6

VEHICLE MASS   =27215.5 KG     DELTA V=  4815.8 M/S    AVE. ISP=3075.2 N-S/KG

TOTAL PROPELLANT                             22193.09 KG
  USABLE FUEL                      5980.68
  USABLE OXIDIZER                 15549.78
  FUEL TRAPPED                      181.19
  OXID TRAPPED                      467.83
  FUEL START-S/D LOSSES               6.80
  OXID START-S/D LOSSES               6.80

OXIDIZER TANKS (NO.= 1)                        350.09
 (TOROIDAL)
  INNER DIA=     1.753 M
  OUTER DIA=     4.267 M
  HEIGHT   =     1.257 M
  VOLUME   =    11.734 M3
  AVG THK  =    .00261 M
  FS = 1.50,  FNOP= 1.30

FUEL TANKS (NO.= 1)                            235.66
 (ELLIPSOIDAL)
  DIAMETER=    2.719 M
  LENGTH  =    1.923 M
  VOLUME  =    7.444 M3
  AVG THK =   .00347 M
  FS = 1.50,  FNOP= 1.30

PRESSURANT                                      42.908

PRESSURANT TANKS (NO.= 1)                      227.75
  DIA=    1.2472 M
  VOL=     1.016 M3
  THK=    .01052 M
  FS = 1.50,  FNOP= 1.10


ENGINES (NO.= 1)                                37.19

COMPONENTS AND LINES                           386.01
ENG. MOUNTS,SUPPORTS                           949.37

TOTAL WET SYSTEM MASS                        24422.1
TOTAL BURNOUT MASS                            2878.0
   (INCL.NON-USABLE PROP. AND GAS)

MASS FRACTION                                     .882
TOTAL IMPULSE                           66214016.7 N-S

             PRESSURE SCHEDULE(N/M2  )  AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =   .2482E+08    INITIAL CHAMBER PRESSURE =0.
INITIAL OX SYS PRESSURE   =   .1069E+07    FINAL OX SYS PRESSURE    =  .1069E+07
INITIAL FU SYS PRESSURE   =   .1207E+07    FINAL FU SYS PRESSURE    =  .1207E+07
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9 BURNS, CONSTANT ACCELERATION, T/M=0.015

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 N2O4/MMH, MIN. LENGTH, PRESSURE FED,                   MR = 1.8

VEHICLE MASS  =27215.5 KG    DELTA V=  4480.6 M/S   AVE. ISP=3176.2 N-S/KG

TOTAL PROPELLANT                          21209.16 KG
  USABLE FUEL                    7348.21
  USABLE OXIDIZER               13226.77
  FUEL TRAPPED                    221.53
  OXID TRAPPED                    398.13
  FUEL START-S/D LOSSES             7.26
  OXID START-S/D LOSSES             7.26

OXIDIZER TANKS (NO.= 1)                     289.85
 (TOROIDAL)
  INNER DIA=     1.994 M
  OUTER DIA=     4.267 M
  HEIGHT   =     1.137 M
  VOLUME   =     9.982 M3
  AVG THK  =    .00229 M
  FS = 1.50,  FNOP= 1.30

FUEL TANKS (NO.= 1)                         289.46
 (ELLIPSOIDAL)
  DIAMETER=    2.912 M
  LENGTH  =    2.059 M
  VOLUME  =    9.143 M3
  AVG THK =   .00372 M
  FS = 1.50,  FNOP= 1.30

PRESSURANT                                  42.791

PRESSURANT TANKS (NO.= 1)                   227.03
  DIA=   1.2459 M
  VOL=     1.013 M3
  THK=    .01051 M
  FS = 1.50,  FNOP= 1.10


ENGINES (NO.= 1)                              4.54

COMPONENTS AND LINES                        386.01
ENG. MOUNTS,SUPPORTS                       1289.11

TOTAL WET SYSTEM MASS                      23737.9
TOTAL BURNOUT MASS                          3148.4
   (INCL.NON-USABLE PROP. AND GAS)

MASS FRACTION                                 .867
TOTAL IMPULSE                         65353809.2 N-S

           PRESSURE SCHEDULE(N/M2   )   AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =   .2482E+08   INITIAL CHAMBER PRESSURE =0.
INITIAL OX SYS PRESSURE   =   .1069E+07   FINAL OX SYS PRESSURE    =  .1069E+07
INITIAL FU SYS PRESSURE   =   .1207E+07   FINAL FU SYS PRESSURE    =  .1207E+07
```

9 BURNS, CONSTANT ACCELERATION, T/M=0.015

N2O4/MMH, MIN. LENGTH, PRESSURE FED, MR = 2.2

VEHICLE MASS =27215.5 KG DELTA V= 4480.6 M/S AVE. ISP=3162.5 N-S/KG

TOTAL PROPELLANT		21250.90 KG
USABLE FUEL	6442.35	
USABLE OXIDIZER	14173.17	
FUEL TRAPPED	194.42	
OXID TRAPPED	426.44	
FUEL START-S/D LOSSES	7.26	
OXID START-S/D LOSSES	7.26	
OXIDIZER TANKS (NO.= 1)		313.76
(TOROIDAL)		
INNER DIA= 1.895 M		
OUTER DIA= 4.267 M		
HEIGHT = 1.186 M		
VOLUME = 10.696 M3		
AVG THK = .00242 M		
FS = 1.50, FNOP= 1.30		
FUEL TANKS (NO.= 1)		253.82
(ELLIPSOIDAL)		
DIAMETER= 2.787 M		
LENGTH = 1.971 M		
VOLUME = 8.018 M3		
AVG THK = .00356 M		
FS = 1.50, FNOP= 1.30		
PRESSURANT		41.869
PRESSURANT TANKS (NO.= 1)		222.19
DIA= 1.2370 M		
VOL= .991 M3		
THK= .01044 M		
FS = 1.50, FNOP= 1.10		
ENGINES (NO.= 1)		4.54
COMPONENTS AND LINES		386.01
ENG. MOUNTS, SUPPORTS		1289.11
TOTAL WET SYSTEM MASS		23762.2
TOTAL BURNOUT MASS		3132.2
(INCL.NON-USABLE PROP. AND GAS)		
MASS FRACTION		.868
TOTAL IMPULSE		65199540.1 N-S

PRESSURE SCHEDULE(N/M2) AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =	.2482E+08	INITIAL CHAMBER PRESSURE =	0.
INITIAL OX SYS PRESSURE =	.1069E+07	FINAL OX SYS PRESSURE =	.1069E+07
INITIAL FU SYS PRESSURE =	.1207E+07	FINAL FU SYS PRESSURE =	.1207E+07

9 BURNS, CONSTANT ACCELERATION, T/M=0.015

N2O4/MMH. MIN. LENGTH. PRESSURE FED.   MR = 2.6

VEHICLE MASS =27215.5 KG   DELTA V= 4480.6 M/S   AVE. ISP=3088.0 N-S/KG

TOTAL PROPELLANT		21478.47 KG
USABLE FUEL	5788.16	
USABLE OXIDIZER	15049.21	
FUEL TRAPPED	174.96	
OXID TRAPPED	451.62	
FUEL START-S/D LOSSES	7.26	
OXID START-S/D LOSSES	7.26	
OXIDIZER TANKS (NO.= 1)		336.62
(TOROIDAL)		
INNER DIA= 1.805 M		
OUTER DIA= 4.267 M		
HEIGHT = 1.231 M		
VOLUME = 11.355 M3		
AVG THK = .00254 M		
FS = 1.50, FNOP= 1.30		
FUEL TANKS (NO.= 1)		228.09
(ELLIPSOIDAL)		
DIAMETER= 2.690 M		
LENGTH = 1.902 M		
VOLUME = 7.205 M3		
AVG THK = .00344 M		
FS = 1.50, FNOP= 1.30		
PRESSURANT		41.529
PRESSURANT TANKS (NO.= 1)		220.43
DIA= 1.2337 M		
VOL= .983 M3		
THK= .01041 M		
FS = 1.50, FNOP= 1.10		
ENGINES (NO.= 1)		4.54
COMPONENTS AND LINES		386.01
ENG. MOUNTS, SUPPORTS		1289.11
TOTAL WET SYSTEM MASS		23984.8
TOTAL BURNOUT MASS		3132.9
(INCL.NON-USABLE PROP. AND GAS)		
MASS FRACTION		.869
TOTAL IMPULSE		64348162.0 N-S

PRESSURE SCHEDULE(N/M2) AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =	.2482E+08	INITIAL CHAMBER PRESSURE =	0.
INITIAL OX SYS PRESSURE =	.1069E+07	FINAL OX SYS PRESSURE =	.1069E+07
INITIAL FU SYS PRESSURE =	.1207E+07	FINAL FU SYS PRESSURE =	.1207E+07

9 BURNS, CONSTANT ACCELERATION, T/M=0.1

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N204/MMH, MIN. LENGTH, PRESSURE FED,                    MR = 1.8

VEHICLE MASS  =27215.5 KG    DELTA V=  4291.6 M/S   AVE. ISP=3229.2 N-S/KG

TOTAL PROPELLANT                               20639.13 KG
  USABLE FUEL                      7146.44
  USABLE OXIDIZER                 12863.59
  FUEL TRAPPED                      215.13
  OXID TRAPPED                      383.13
  FUEL START-S/D LOSSES              15.42
  OXID START-S/D LOSSES              15.42

OXIDIZER TANKS (NO.= 1)                          280.97
 (TOROIDAL)
  INNER DIA=     2.031 M
  OUTER DIA=     4.267 M
  HEIGHT   =     1.118 M
  VOLUME   =     9.711 M3
  AVG THK  =    .00225 M
  FS = 1.50,  FNOP= 1.30

FUEL TANKS (NO.= 1)                              281.82
 (ELLIPSOIDAL)
  DIAMETER=     2.886 M
  LENGTH  =     2.041 M
  VOLUME  =     8.902 M3
  AVG THK =    .00369 M
  FS = 1.50,  FNOP= 1.30

PRESSURANT                                       41.643

PRESSURANT TANKS (NO.= 1)                        220.94
  DIA=    1.2346 M
  VOL=      .985 M3
  THK=    .01042 M
  FS = 1.50,  FNOP= 1.10


ENGINES (NO.= 1)                                   5.44

COMPONENTS AND LINES                             386.01
ENG. MOUNTS,SUPPORTS                            1275.05

TOTAL WET SYSTEM MASS                           23131.0
TOTAL BURNOUT MASS                               3090.1
   (INCL.NON-USABLE PROP. AND GAS)

MASS FRACTION                                      .865
TOTAL IMPULSE                               64618954.6 N-S

             PRESSURE SCHEDULE(N/M2  )  AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =   .2482E+08    INITIAL CHAMBER PRESSURE =0.
INITIAL OX SYS PRESSURE   =   .1069E+07    FINAL OX SYS PRESSURE    =  .1069E+07
INITIAL FU SYS PRESSURE   =   .1207E+07    FINAL FU SYS PRESSURE    =  .1207E+07
```

9 BURNS, CONSTANT ACCELERATION, T/M=0.1

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   N2O4/MMH, MIN. LENGTH, PRESSURE FED,              MR = 2.2

VEHICLE MASS  =27215.5 KG    DELTA V=  4291.6 M/S   AVE. ISP=3208.6 N-S/KG

TOTAL PROPELLANT                              20704.77 KG
  USABLE FUEL                        6272.26
  USABLE OXIDIZER                   13798.97
  FUEL TRAPPED                        188.81
  OXID TRAPPED                        413.90
  FUEL START-S/D LOSSES                15.42
  OXID START-S/D LOSSES                15.42

OXIDIZER TANKS (NO.= 1)                         304.38
 (TOROIDAL)
  INNER DIA=     1.933 M
  OUTER DIA=     4.267 M
  HEIGHT   =     1.167 M
  VOLUME   =    10.418 M3
  AVG THK  =    .00237 M
  FS = 1.50,  FNOP= 1.30

FUEL TANKS (NO.= 1)                             247.42
 (ELLIPSOIDAL)
  DIAMETER=     2.764 M
  LENGTH  =     1.954 M
  VOLUME  =     7.815 M3
  AVG THK =    .00353 M
  FS = 1.50,  FNOP= 1.30

PRESSURANT                                      40.791

PRESSURANT TANKS (NO.= 1)                       216.47
  DIA=    1.2263 M
  VOL=      .965 M3
  THK=    .01035 M
  FS = 1.50,  FNOP= 1.10


ENGINES (NO.= 1)                                  5.44

COMPONENTS AND LINES                            386.01
ENG. MOUNTS,SUPPORTS                           1275.05

TOTAL WET SYSTEM MASS                          23180.3
TOTAL BURNOUT MASS                              3078.3
   (INCL.NON-USABLE PROP. AND GAS)

MASS FRACTION                                     .866
TOTAL IMPULSE                            64403232.0 N-S

             PRESSURE SCHEDULE(N/M2  )   AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =   .2482E+08    INITIAL CHAMBER PRESSURE =0.
INITIAL OX SYS PRESSURE   =   .1069E+07    FINAL OX SYS PRESSURE    =  .1069E+07
INITIAL FU SYS PRESSURE   =   .1207E+07    FINAL FU SYS PRESSURE    =  .1207E+07
```

9 BURNS, CONSTANT ACCELERATION, T/M=0.1

N2O4/MMH, MIN. LENGTH, PRESSURE FED, MR = 2.6

VEHICLE MASS =27215.5 KG DELTA V= 4291.6 M/S AVE. ISP=3140.9 N-S/KG

TOTAL PROPELLANT		20912.92 KG
USABLE FUEL	5631.70	
USABLE OXIDIZER	14642.43	
FUEL TRAPPED	169.69	
OXID TRAPPED	438.26	
FUEL START-S/D LOSSES	15.42	
OXID START-S/D LOSSES	15.42	
OXIDIZER TANKS (NO.= 1)		326.08
(TOROIDAL)		
INNER DIA= 1.846 M		
OUTER DIA= 4.267 M		
HEIGHT = 1.211 M		
VOLUME = 11.054 M3		
AVG THK = .00248 M		
FS = 1.50, FNOP= 1.30		
FUEL TANKS (NO.= 1)		222.22
(ELLIPSOIDAL)		
DIAMETER= 2.666 M		
LENGTH = 1.885 M		
VOLUME = 7.019 M3		
AVG THK = .00341 M		
FS = 1.50, FNOP= 1.30		
PRESSURANT		40.433
PRESSURANT TANKS (NO.= 1)		214.61
DIA= 1.2227 M		
VOL= .957 M3		
THK= .01032 M		
FS = 1.50, FNOP= 1.10		
ENGINES (NO.= 1)		5.44
COMPONENTS AND LINES		386.01
ENG. MOUNTS, SUPPORTS		1275.05
TOTAL WET SYSTEM MASS		23382.8
TOTAL BURNOUT MASS		3077.8
(INCL.NON-USABLE PROP. AND GAS)		
MASS FRACTION		.867
TOTAL IMPULSE		63682438.5 N-S

PRESSURE SCHEDULE(N/M2) AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =	.2482E+08	INITIAL CHAMBER PRESSURE =	0.
INITIAL OX SYS PRESSURE =	.1069E+07	FINAL OX SYS PRESSURE =	.1069E+07
INITIAL FU SYS PRESSURE =	.1207E+07	FINAL FU SYS PRESSURE =	.1207E+07

9 BURNS, CONSTANT ACCELERATION, T/M=0.01

N2O4/MMH, MAX. PERF., PUMP FED,   MR = 1.8

VEHICLE MASS =27215.5 KG   DELTA V= 4815.8 M/S   AVE. ISP=3185.1 N-S/KG

```
TOTAL PROPELLANT                              21855.73 KG
  USABLE FUEL                       7576.80
  USABLE OXIDIZER                  13638.24
  FUEL TRAPPED                       224.55
  OXID TRAPPED                       402.53
  FUEL START-S/D LOSSES                6.80
  OXID START-S/D LOSSES                6.80

OXIDIZER TANKS (NO.= 1)                          93.04
 (ELLIPSOIDAL)
  DIAMETER=     3.029 M
  LENGTH   =    2.142 M
  VOLUME   =   10.286 M3
  AVG THK  =   .00111 M
  FS = 1.50,  FNOP= 1.30

FUEL TANKS (NO.= 1)                              50.40
 (ELLIPSOIDAL)
  DIAMETER=     2.941 M
  LENGTH   =    2.080 M
  VOLUME   =    9.422 M3
  AVG THK  =   .00064 M
  FS = 1.50,  FNOP= 1.30

PRESSURANT                                       3.606

PRESSURANT TANKS (NO.= 1)                        18.89
  DIA=     .5439 M
  VOL=      .084 M3
  THK=    .00459 M
  FS = 1.50,  FNOP= 1.10

ENGINES (NO.= 1)                                 37.19

COMPONENTS AND LINES                            363.33
ENG. MOUNTS,SUPPORTS                            949.37

TOTAL WET SYSTEM MASS                          23371.6
TOTAL BURNOUT MASS                              2142.9
   (INCL.NON-USABLE PROP. AND GAS)

MASS FRACTION                                     .908
TOTAL IMPULSE                             67574119.3 N-S

            PRESSURE SCHEDULE(N/M2  )   AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =   .2482E+08   INITIAL CHAMBER PRESSURE =0.
INITIAL OX SYS PRESSURE   =   .1379E+06   FINAL OX SYS PRESSURE    =  .1379E+06
INITIAL FU SYS PRESSURE   =   .1034E+06   FINAL FU SYS PRESSURE    =  .1034E+06
```

9 BURNS, CONSTANT ACCELERATION, T/M=0.01

N2O4/MMH, MAX. PERF., PUMP FED, MR = 2.2

VEHICLE MASS =27215.5 KG   DELTA V= 4815.8 M/S   AVE. ISP=3191.9 N-S/KG

TOTAL PROPELLANT		21835.88 KG
USABLE FUEL	6623.59	
USABLE OXIDIZER	14571.91	
FUEL TRAPPED	196.26	
OXID TRAPPED	430.52	
FUEL START-S/D LOSSES	6.80	
OXID START-S/D LOSSES	6.80	
OXIDIZER TANKS (NO.= 1)		99.41
(ELLIPSOIDAL)		
DIAMETER= 3.096 M		
LENGTH = 2.189 M		
VOLUME = 10.990 M3		
AVG THK = .00113 M		
FS = 1.50, FNOP= 1.30		
FUEL TANKS (NO.= 1)		46.08
(ELLIPSOIDAL)		
DIAMETER= 2.813 M		
LENGTH = 1.989 M		
VOLUME = 8.238 M3		
AVG THK = .00064 M		
FS = 1.50, FNOP= 1.30		
PRESSURANT		3.518
PRESSURANT TANKS (NO.= 1)		18.42
DIA= .5393 M		
VOL= .082 M3		
THK= .00455 M		
FS = 1.50, FNOP= 1.10		
ENGINES (NO.= 1)		37.19
COMPONENTS AND LINES		363.33
ENG. MOUNTS, SUPPORTS		949.37
TOTAL WET SYSTEM MASS		23353.2
TOTAL BURNOUT MASS		2144.1
(INCL.NON-USABLE PROP. AND GAS)		
MASS FRACTION		.908
TOTAL IMPULSE		67657372.7 N-S

PRESSURE SCHEDULE(N/M2) AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =	.2482E+08	INITIAL CHAMBER PRESSURE =	0.
INITIAL OX SYS PRESSURE =	.1379E+06	FINAL OX SYS PRESSURE =	.1379E+06
INITIAL FU SYS PRESSURE =	.1034E+06	FINAL FU SYS PRESSURE =	.1034E+06

9 BURNS, CONSTANT ACCELERATION, T/M=0.01

N2O4/MMH, MAX. PERF., PUMP FED, MR = 2.6

VEHICLE MASS =27215.5 KG DELTA V= 4815.8 M/S AVE. ISP=3111.5 N-S/KG

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TOTAL PROPELLANT                          22072.02 KG
  USABLE FUEL                  5951.58
  USABLE OXIDIZER             15474.12
  FUEL TRAPPED                  176.36
  OXID TRAPPED                  456.36
  FUEL START-S/D LOSSES           6.80
  OXID START-S/D LOSSES           6.80

OXIDIZER TANKS (NO.= 1)                     105.56
 (ELLIPSOIDAL)
  DIAMETER=     3.159 M
  LENGTH  =     2.234 M
  VOLUME  =    11.670 M3
  AVG THK =    .00115 M
  FS = 1.50,  FNOP= 1.30

FUEL TANKS (NO.= 1)                          42.91
 (ELLIPSOIDAL)
  DIAMETER=     2.714 M
  LENGTH  =     1.919 M
  VOLUME  =     7.403 M3
  AVG THK =    .00064 M
  FS = 1.50,  FNOP= 1.30

PRESSURANT                                    3.490

PRESSURANT TANKS (NO.= 1)                    18.26
  DIA=     .5378 M
  VOL=      .081 M3
  THK=    .00454 M
  FS = 1.50,  FNOP= 1.10


ENGINES (NO.= 1)                             37.19

COMPONENTS AND LINES                        363.33
ENG. MOUNTS,SUPPORTS                        949.37

TOTAL WET SYSTEM MASS                      23592.1
TOTAL BURNOUT MASS                          2152.8
   (INCL.NON-USABLE PROP. AND GAS)

MASS FRACTION                                 .908
TOTAL IMPULSE                       66669249.4 N-S

             PRESSURE SCHEDULE(N/M2  )   AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =   .2482E+08    INITIAL CHAMBER PRESSURE =0.
INITIAL OX SYS PRESSURE   =   .1379E+06    FINAL OX SYS PRESSURE    =  .1379E+06
INITIAL FU SYS PRESSURE   =   .1034E+06    FINAL FU SYS PRESSURE    =  .1034E+06
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9 BURNS, CONSTANT ACCELERATION, T/M=0.015

```
     N2O4/MMH, MAX. PERF., PUMP FED,                 MR = 1.8

VEHICLE MASS  =27215.5 KG    DELTA V=  4480.6 M/S   AVE. ISP=3209.6 N-S/KG

TOTAL PROPELLANT                           21095.00 KG
  USABLE FUEL                     7313.20
  USABLE OXIDIZER                13163.76
  FUEL TRAPPED                     216.09
  OXID TRAPPED                     387.43
  FUEL START-S/D LOSSES              7.26
  OXID START-S/D LOSSES              7.26

OXIDIZER TANKS (NO.= 1)                       89.80
 (ELLIPSOIDAL)
  DIAMETER=     2.993 M
  LENGTH  =     2.116 M
  VOLUME  =     9.928 M3
  AVG THK =    .00109 M
  FS = 1.50,  FNOP= 1.30

FUEL TANKS (NO.= 1)                           49.22
 (ELLIPSOIDAL)
  DIAMETER=     2.907 M
  LENGTH  =     2.056 M
  VOLUME  =     9.095 M3
  AVG THK =    .00064 M
  FS = 1.50,  FNOP= 1.30

PRESSURANT                                    3.478

PRESSURANT TANKS (NO.= 1)                     18.23
  DIA=     .5375 M
  VOL=      .081 M3
  THK=    .00454 M
  FS = 1.50,  FNOP= 1.10


ENGINES (NO.= 1)                              42.18

COMPONENTS AND LINES                         363.33
ENG. MOUNTS,SUPPORTS                         944.83

TOTAL WET SYSTEM MASS                       22606.1
TOTAL BURNOUT MASS                           2114.6
   (INCL.NON-USABLE PROP. AND GAS)

MASS FRACTION                                  .906
TOTAL IMPULSE                           65725208.9 N-S

            PRESSURE SCHEDULE(N/M2  )  AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =   .2482E+08   INITIAL CHAMBER PRESSURE =0.
INITIAL OX SYS PRESSURE   =   .1379E+06   FINAL OX SYS PRESSURE    =  .1379E+06
INITIAL FU SYS PRESSURE   =   .1034E+06   FINAL FU SYS PRESSURE    =  .1034E+06
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9 BURNS, CONSTANT ACCELERATION, T/M=0.015

N204/MMH, MAX. PERF., PUMP FED, MR = 2.2

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VEHICLE MASS  =27215.5 KG    DELTA V=  4480.6 M/S   AVE. ISP=3216.4 N-S/KG

TOTAL PROPELLANT                                  21074.57 KG
  USABLE FUEL                          6392.77
  USABLE OXIDIZER                     14064.09
  FUEL TRAPPED                          189.07
  OXID TRAPPED                          414.13
  FUEL START-S/D LOSSES                   7.26
  OXID START-S/D LOSSES                   7.26

OXIDIZER TANKS (NO.= 1)                              95.94
 (ELLIPSOIDAL)
  DIAMETER=    3.060 M
  LENGTH  =    2.164 M
  VOLUME  =   10.607 M3
  AVG THK =   .00112 M
  FS = 1.50,  FNOP= 1.30

FUEL TANKS (NO.= 1)                                  45.01
 (ELLIPSOIDAL)
  DIAMETER=    2.780 M
  LENGTH  =    1.965 M
  VOLUME  =    7.951 M3
  AVG THK =   .00064 M
  FS = 1.50,  FNOP= 1.30

PRESSURANT                                           3,393

PRESSURANT TANKS (NO.= 1)                            17.77
  DIA=     .5330 M
  VOL=      .079 M3
  THK=    .00450 M
  FS = 1.50,  FNOP= 1.10


ENGINES (NO.= 1)                                     42.18

COMPONENTS AND LINES                                363.33
ENG. MOUNTS,SUPPORTS                                944.83

TOTAL WET SYSTEM MASS                             22587.0
TOTAL BURNOUT MASS                                 2115.7
   (INCL.NON-USABLE PROP. AND GAS)

MASS FRACTION                                        .906
TOTAL IMPULSE                                 65801106.4 N-S

             PRESSURE SCHEDULE(N/M2  )   AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =   .2482E+08   INITIAL CHAMBER PRESSURE =0.
INITIAL OX SYS PRESSURE   =   .1379E+06   FINAL OX SYS PRESSURE    =  .1379E+06
INITIAL FU SYS PRESSURE   =   .1034E+06   FINAL FU SYS PRESSURE    =  .1034E+06
```

9 BURNS, CONSTANT ACCELERATION, T/M=0.015

N2O4/MMH, MAX. PERF., PUMP FED, MR = 2.6

VEHICLE MASS =27215.5 KG DELTA V= 4480.6 M/S AVE. ISP=3141.9 N-S/KG

TOTAL PROPELLANT		21299.90 KG
USABLE FUEL	5743.48	
USABLE OXIDIZER	14933.04	
FUEL TRAPPED	169.73	
OXID TRAPPED	439.13	
FUEL START-S/D LOSSES	7.26	
OXID START-S/D LOSSES	7.26	
OXIDIZER TANKS (NO.= 1) (ELLIPSOIDAL)		101.86
DIAMETER= 3.122 M		
LENGTH = 2.207 M		
VOLUME = 11.261 M3		
AVG THK = .00114 M		
FS = 1.50, FNOP= 1.30		
FUEL TANKS (NO.= 1) (ELLIPSOIDAL)		41.91
DIAMETER= 2.682 M		
LENGTH = 1.897 M		
VOLUME = 7.144 M3		
AVG THK = .00064 M		
FS = 1.50, FNOP= 1.30		
PRESSURANT		3.366
PRESSURANT TANKS (NO.= 1)		17.62
DIA= .5314 M		
VOL= .079 M3		
THK= .00448 M		
FS = 1.50, FNOP= 1.10		
ENGINES (NO.= 1)		42.18
COMPONENTS AND LINES		363.33
ENG. MOUNTS, SUPPORTS		944.83
TOTAL WET SYSTEM MASS		22815.0
TOTAL BURNOUT MASS (INCL.NON-USABLE PROP. AND GAS)		2124.0
MASS FRACTION		.906
TOTAL IMPULSE		64966654.5 N-S

PRESSURE SCHEDULE(N/M2) AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =	.2482E+08	INITIAL CHAMBER PRESSURE =	0.
INITIAL OX SYS PRESSURE =	.1379E+06	FINAL OX SYS PRESSURE =	.1379E+06
INITIAL FU SYS PRESSURE =	.1034E+06	FINAL FU SYS PRESSURE =	.1034E+06

9 BURNS, CONSTANT ACCELERATION, T/M=0.05

N2O4/MMH, MAX. PERF., PUMP FED, MR = 2.2

VEHICLE MASS =27215.5 KG DELTA V= 4303.8 M/S AVE. ISP=3265.5 N-S/KG

TOTAL PROPELLANT		20561.01 KG
USABLE FUEL	6228.15	
USABLE OXIDIZER	13701.94	
FUEL TRAPPED	190.86	
OXID TRAPPED	418.28	
FUEL START-S/D LOSSES	10.89	
OXID START-S/D LOSSES	10.89	
OXIDIZER TANKS (NO.= 1)		93.59
(ELLIPSOIDAL)		
DIAMETER= 3.035 M		
LENGTH = 2.146 M		
VOLUME = 10.347 M3		
AVG THK = .00111 M		
FS = 1.50, FNOP= 1.30		
FUEL TANKS (NO.= 1)		44.28
(ELLIPSOIDAL)		
DIAMETER= 2.757 M		
LENGTH = 1.950 M		
VOLUME = 7.759 M3		
AVG THK = .00064 M		
FS = 1.50, FNOP= 1.30		
PRESSURANT		3.307
PRESSURANT TANKS (NO.= 1)		17.32
DIA= .5284 M		
VOL= .077 M3		
THK= .00446 M		
FS = 1.50, FNOP= 1.10		
ENGINES (NO.= 1)		68.04
COMPONENTS AND LINES		363.33
ENG. MOUNTS, SUPPORTS		940.75
TOTAL WET SYSTEM MASS		22091.6
TOTAL BURNOUT MASS		2139.8
(INCL.NON-USABLE PROP. AND GAS)		
MASS FRACTION		.902
TOTAL IMPULSE		65083972.0 N-S

PRESSURE SCHEDULE(N/M2) AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =	.2482E+08	INITIAL CHAMBER PRESSURE =	0.
INITIAL OX SYS PRESSURE =	.1379E+06	FINAL OX SYS PRESSURE =	.1379E+06
INITIAL FU SYS PRESSURE =	.1034E+06	FINAL FU SYS PRESSURE =	.1034E+06

9 BURNS, CONSTANT ACCELERATION, T/M=0.1

N2O4/MMH, MAX. PERF., PUMP FED, MR = 1.8

VEHICLE MASS =27215.5 KG DELTA V= 4291.6 M/S AVE. ISP=3266.4 N-S/KG

TOTAL PROPELLANT		20515.35 KG
USABLE FUEL	7107.13	
USABLE OXIDIZER	12792.83	
FUEL TRAPPED	209.12	
OXID TRAPPED	375.42	
FUEL START-S/D LOSSES	15.42	
OXID START-S/D LOSSES	15.42	
OXIDIZER TANKS (NO.= 1)		87.32
(ELLIPSOIDAL)		
DIAMETER= 2.965 M		
LENGTH = 2.097 M		
VOLUME = 9.653 M3		
AVG THK = .00108 M		
FS = 1.50, FNOP= 1.30		
FUEL TANKS (NO.= 1)		48.33
(ELLIPSOIDAL)		
DIAMETER= 2.880 M		
LENGTH = 2.037 M		
VOLUME = 8.847 M3		
AVG THK = .00064 M		
FS = 1.50, FNOP= 1.30		
PRESSURANT		3.385
PRESSURANT TANKS (NO.= 1)		17.73
DIA= .5326 M		
VOL= .079 M3		
THK= .00449 M		
FS = 1.50, FNOP= 1.10		
ENGINES (NO.= 1)		100.24
COMPONENTS AND LINES		363.33
ENG. MOUNTS,SUPPORTS		941.66
TOTAL WET SYSTEM MASS		22077.3
TOTAL BURNOUT MASS		2146.5
(INCL.NON-USABLE PROP. AND GAS)		
MASS FRACTION		.901
TOTAL IMPULSE		65005073.5 N-S

PRESSURE SCHEDULE(N/M2) AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =	.2482E+08	INITIAL CHAMBER PRESSURE =	0.
INITIAL OX SYS PRESSURE =	.1379E+06	FINAL OX SYS PRESSURE =	.1379E+06
INITIAL FU SYS PRESSURE =	.1034E+06	FINAL FU SYS PRESSURE =	.1034E+06

9 BURNS, CONSTANT ACCELERATION, T/M=0.1

N2O4/MMH, MAX. PERF., PUMP FED, MR = 2.2

VEHICLE MASS =27215.5 KG DELTA V= 4291.6 M/S AVE. ISP=3288.0 N-S/KG

TOTAL PROPELLANT		20450.60 KG
USABLE FUEL	6198.94	
USABLE OXIDIZER	13637.68	
FUEL TRAPPED	182.85	
OXID TRAPPED	400.28	
FUEL START-S/D LOSSES	15.42	
OXID START-S/D LOSSES	15.42	

OXIDIZER TANKS (NO.= 1) 93.08
(ELLIPSOIDAL)
DIAMETER= 3.029 M
LENGTH = 2.142 M
VOLUME = 10.290 M3
AVG THK = .00111 M
FS = 1.50, FNOP= 1.30

FUEL TANKS (NO.= 1) 44.13
(ELLIPSOIDAL)
DIAMETER= 2.752 M
LENGTH = 1.946 M
VOLUME = 7.720 M3
AVG THK = .00064 M
FS = 1.50, FNOP= 1.30

PRESSURANT 3.295

PRESSURANT TANKS (NO.= 1) 17.25
DIA= .5277 M
VOL= .077 M3
THK= .00445 M
FS = 1.50, FNOP= 1.10

ENGINES (NO.= 1) 100.24

COMPONENTS AND LINES 363.33
ENG. MOUNTS,SUPPORTS 941.66

TOTAL WET SYSTEM MASS 22013.6
TOTAL BURNOUT MASS 2146.1
(INCL.NON-USABLE PROP. AND GAS)

MASS FRACTION .901
TOTAL IMPULSE 65226155.8 N-S

PRESSURE SCHEDULE(N/M2) AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =	.2482E+08	INITIAL CHAMBER PRESSURE =	0.
INITIAL OX SYS PRESSURE =	.1379E+06	FINAL OX SYS PRESSURE =	.1379E+06
INITIAL FU SYS PRESSURE =	.1034E+06	FINAL FU SYS PRESSURE =	.1034E+06

9 BURNS, CONSTANT ACCELERATION, T/M=0.1

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   N2O4/MMH, MAX. PERF., PUMP FED,               MR = 2.6

VEHICLE MASS  =27215.5 KG    DELTA V=  4291.6 M/S    AVE. ISP=3230.2 N-S/KG

TOTAL PROPELLANT                           20625.07 KG
  USABLE FUEL                     5557.53
  USABLE OXIDIZER                14449.59
  FUEL TRAPPED                     163.71
  OXID TRAPPED                     423.39
  FUEL START-S/D LOSSES             15.42
  OXID START-S/D LOSSES             15.42

OXIDIZER TANKS (NO.= 1)                       98.61
 (ELLIPSOIDAL)
  DIAMETER=     3.088 M
  LENGTH  =     2.184 M
  VOLUME  =    10.902 M3
  AVG THK =    .00113 M
  FS = 1.50,   FNOP= 1.30

FUEL TANKS (NO.= 1)                           41.04
 (ELLIPSOIDAL)
  DIAMETER=     2.654 M
  LENGTH  =     1.877 M
  VOLUME  =     6.923 M3
  AVG THK =    .00064 M
  FS = 1.50,   FNOP= 1.30

PRESSURANT                                    3.261

PRESSURANT TANKS (NO.= 1)                     17.06
  DIA=     .5257 M
  VOL=      .076 M3
  THK=    .00444 M
  FS = 1.50,   FNOP= 1.10


ENGINES (NO.= 1)                             100.24

COMPONENTS AND LINES                         363.33
ENG. MOUNTS,SUPPORTS                         941.66

TOTAL WET SYSTEM MASS                      22190.3
TOTAL BURNOUT MASS                          2152.3
   (INCL.NON-USABLE PROP. AND GAS)

MASS FRACTION                                 .902
TOTAL IMPULSE                          64629185.2 N-S

             PRESSURE SCHEDULE(N/M2  )   AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =   .2482E+08    INITIAL CHAMBER PRESSURE =0.
INITIAL OX SYS PRESSURE   =   .1379E+06    FINAL OX SYS PRESSURE    =  .1379E+06
INITIAL FU SYS PRESSURE   =   .1034E+06    FINAL FU SYS PRESSURE    =  .1034E+06
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9 BURNS, CONSTANT ACCELERATION, T/M=0.01

N2O4/MMH, MIN. LENGTH, PUMP FED, MR = 1.8

VEHICLE MASS =27215.5 KG DELTA V= 4815.8 M/S AVE. ISP=3185.1 N-S/KG

TOTAL PROPELLANT		21869.40 KG
USABLE FUEL	7576.80	
USABLE OXIDIZER	13638.24	
FUEL TRAPPED	229.11	
OXID TRAPPED	411.64	
FUEL START-S/D LOSSES	6.80	
OXID START-S/D LOSSES	6.80	

OXIDIZER TANKS (NO.= 1) 98.71
(TOROIDAL)
INNER DIA= 1.950 M
OUTER DIA= 4.267 M
HEIGHT = 1.158 M
VOLUME = 10.293 M3
AVG THK = .00077 M
FS = 1.50, FNOP= 1.30

FUEL TANKS (NO.= 1) 50.42
(ELLIPSOIDAL)
DIAMETER= 2.942 M
LENGTH = 2.080 M
VOLUME = 9.428 M3
AVG THK = .00064 M
FS = 1.50, FNOP= 1.30

PRESSURANT 3.606

PRESSURANT TANKS (NO.= 1) 18.89
DIA= .5439 M
VOL= .084 M3
THK= .00459 M
FS = 1.50, FNOP= 1.10

ENGINES (NO.= 1) 37.19

COMPONENTS AND LINES 386.01
ENG. MOUNTS,SUPPORTS 949.37

TOTAL WET SYSTEM MASS 23413.6
TOTAL BURNOUT MASS 2185.0
(INCL.NON-USABLE PROP. AND GAS)

MASS FRACTION .906
TOTAL IMPULSE 67574119.3 N-S

PRESSURE SCHEDULE(N/M2) AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =	.2482E+08	INITIAL CHAMBER PRESSURE =	0.
INITIAL OX SYS PRESSURE =	.1379E+06	FINAL OX SYS PRESSURE =	.1379E+06
INITIAL FU SYS PRESSURE =	.1034E+06	FINAL FU SYS PRESSURE =	.1034E+06

9 BURNS, CONSTANT ACCELERATION, T/M=0.01

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N2O4/MMH, MIN. LENGTH, PUMP FED,              MR = 2.2

VEHICLE MASS  =27215.5 KG    DELTA V=  4815.8 M/S   AVE. ISP=3191.9 N-S/KG

TOTAL PROPELLANT                              21849.56 KG
  USABLE FUEL                      6623.59
  USABLE OXIDIZER                 14571.91
  FUEL TRAPPED                      200.81
  OXID TRAPPED                      439.64
  FUEL START-S/D LOSSES               6.80
  OXID START-S/D LOSSES               6.80

OXIDIZER TANKS (NO.= 1)                          105.09
 (TOROIDAL)
  INNER DIA=     1.854 M
  OUTER DIA=     4.267 M
  HEIGHT   =     1.207 M
  VOLUME   =    10.997 M3
  AVG THK  =    .00080 M
  FS = 1.50,  FNOP= 1.30

FUEL TANKS (NO.= 1)                               46.10
 (ELLIPSOIDAL)
  DIAMETER=     2.813 M
  LENGTH  =     1.989 M
  VOLUME  =     8.243 M3
  AVG THK =    .00064 M
  FS = 1.50,  FNOP= 1.30

PRESSURANT                                        3.518

PRESSURANT TANKS (NO.= 1)                         18.42
  DIA=     .5393 M
  VOL=      .082 M3
  THK=    .00455 M
  FS = 1.50,  FNOP= 1.10


ENGINES (NO.= 1)                                  37.19

COMPONENTS AND LINES                             386.01
ENG. MOUNTS,SUPPORTS                             949.37

TOTAL WET SYSTEM MASS                           23395.3
TOTAL BURNOUT MASS                               2186.2
   (INCL.NON-USABLE PROP. AND GAS)

MASS FRACTION                                      .906
TOTAL IMPULSE                          67657372.7 N-S

             PRESSURE SCHEDULE(N/M2  )   AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =   .2482E+08   INITIAL CHAMBER PRESSURE =0.
INITIAL OX SYS PRESSURE   =   .1379E+06   FINAL OX SYS PRESSURE    =  .1379E+06
INITIAL FU SYS PRESSURE   =   .1034E+06   FINAL FU SYS PRESSURE    =  .1034E+06
```

9 BURNS, CONSTANT ACCELERATION, T/M=0.01

N2O4/MMH, MIN. LENGTH, PUMP FED   MR = 2.6

VEHICLE MASS =27215.5 KG   DELTA V= 4815.8 M/S   AVE. ISP=3111.5 N-S/KG

```
TOTAL PROPELLANT                                22085.70 KG
  USABLE FUEL                         5951.58
  USABLE OXIDIZER                    15474.12
  FUEL TRAPPED                         180.46
  OXID TRAPPED                         465.93
  FUEL START-S/D LOSSES                  6.80
  OXID START-S/D LOSSES                  6.80

OXIDIZER TANKS (NO.= 1)                            112.27
 (TOROIDAL)
  INNER DIA=     1.761 M
  OUTER DIA=     4.267 M
  HEIGHT   =     1.253 M
  VOLUME   =    11.677 M3
  AVG THK  =    .00084 M
  FS = 1.50,  FNOP= 1.30

FUEL TANKS (NO.= 1)                                 42.93
 (ELLIPSOIDAL)
  DIAMETER=     2.715 M
  LENGTH  =     1.920 M
  VOLUME  =     7.408 M3
  AVG THK =    .00064 M
  FS = 1.50,  FNOP= 1.30

PRESSURANT                                          3.490

PRESSURANT TANKS (NO.= 1)                           18.26
  DIA=     .5378 M
  VOL=      .081 M3
  THK=    .00454 M
  FS = 1.50,  FNOP= 1.10

ENGINES (NO.= 1)                                    37.19

COMPONENTS AND LINES                               386.01
ENG. MOUNTS,SUPPORTS                               949.37

TOTAL WET SYSTEM MASS                             23635.2
TOTAL BURNOUT MASS                                 2195.9
   (INCL.NON-USABLE PROP. AND GAS)

MASS FRACTION                                        .907
TOTAL IMPULSE                                66669249.4 N-S

              PRESSURE SCHEDULE(N/M2  )   AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =   .2482E+08   INITIAL CHAMBER PRESSURE =0.
INITIAL OX SYS PRESSURE   =   .1379E+06   FINAL OX SYS PRESSURE    =  .1379E+06
INITIAL FU SYS PRESSURE   =   .1034E+06   FINAL FU SYS PRESSURE    =  .1034E+06
```

9 BURNS, CONSTANT ACCELERATION, T/M=0.015

N204/MMH, MIN. LENGTH, PUMP FED, MR = 1.8

VEHICLE MASS =27215.5 KG DELTA V= 4480.6 M/S AVE. ISP=3209.6 N-S/KG

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TOTAL PROPELLANT                             21108.67 KG
  USABLE FUEL                     7313.20
  USABLE OXIDIZER                13163.76
  FUEL TRAPPED                     220.65
  OXID TRAPPED                     396.55
  FUEL START-S/D LOSSES              7.26
  OXID START-S/D LOSSES              7.26

OXIDIZER TANKS (NO.= 1)                          95.55
 (TOROIDAL)
  INNER DIA=    2.000 M
  OUTER DIA=    4.267 M
  HEIGHT   =    1.134 M
  VOLUME   =    9.935 M3
  AVG THK  =   .00076 M
  FS = 1.50,  FNOP= 1.30

FUEL TANKS (NO.= 1)                              49.24
 (ELLIPSOIDAL)
  DIAMETER=     2.908 M
  LENGTH  =     2.056 M
  VOLUME  =     9.100 M3
  AVG THK =    .00064 M
  FS = 1.50,  FNOP= 1.30

PRESSURANT                                        3.478

PRESSURANT TANKS (NO.= 1)                        18.23
  DIA=     .5375 M
  VOL=      .081 M3
  THK=    .00454 M
  FS = 1.50,  FNOP= 1.10

ENGINES (NO.= 1)                                 42.18

COMPONENTS AND LINES                            386.01
ENG. MOUNTS,SUPPORTS                           1289.11

TOTAL WET SYSTEM MASS                         22992.5
TOTAL BURNOUT MASS                             2501.0
   (INCL.NON-USABLE PROP. AND GAS)

MASS FRACTION                                    .891
TOTAL IMPULSE                          65725208.9 N-S

            PRESSURE SCHEDULE(N/M2  )   AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =  .2482E+08   INITIAL CHAMBER PRESSURE =0.
INITIAL OX SYS PRESSURE   =  .1379E+06   FINAL OX SYS PRESSURE    =  .1379E+06
INITIAL FU SYS PRESSURE   =  .1034E+06   FINAL FU SYS PRESSURE    =  .1034E+06
```

9 BURNS,CONSTANT ACCELERATION, T/M=0.015

N204/MMH, MIN. LENGTH, PUMP FED,   MR = 2.2

VEHICLE MASS =27215.5 KG   DELTA V= 4480.6 M/S   AVE. ISP=3216.4 N-S/KG

TOTAL PROPELLANT		21088.25 KG
USABLE FUEL	6392.77	
USABLE OXIDIZER	14064.09	
FUEL TRAPPED	193.17	
OXID TRAPPED	423.70	
FUEL START-S/D LOSSES	7.26	
OXID START-S/D LOSSES	7.26	
OXIDIZER TANKS (NO.= 1)		101.59
(TOROIDAL)		
INNER DIA= 1.906 M		
OUTER DIA= 4.267 M		
HEIGHT = 1.181 M		
VOLUME = 10.614 M3		
AVG THK = .00079 M		
FS = 1.50, FNOP= 1.30		
FUEL TANKS (NO.= 1)		45.03
(ELLIPSOIDAL)		
DIAMETER= 2.780 M		
LENGTH = 1.966 M		
VOLUME = 7.956 M3		
AVG THK = .00064 M		
FS = 1.50, FNOP= 1.30		
PRESSURANT		3.393
PRESSURANT TANKS (NO.= 1)		17.77
DIA= .5330 M		
VOL= .079 M3		
THK= .00450 M		
FS = 1.50, FNOP= 1.10		
ENGINES (NO.= 1)		42.18
COMPONENTS AND LINES		386.01
ENG. MOUNTS,SUPPORTS		1289.11
TOTAL WET SYSTEM MASS		22973.3
TOTAL BURNOUT MASS		2502.0
(INCL.NON-USABLE PROP. AND GAS)		
MASS FRACTION		.890
TOTAL IMPULSE		65801106.4 N-S

PRESSURE SCHEDULE(N/M2)   AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =	.2482E+08	INITIAL CHAMBER PRESSURE =	0.
INITIAL OX SYS PRESSURE =	.1379E+06	FINAL OX SYS PRESSURE =	.1379E+06
INITIAL FU SYS PRESSURE =	.1034E+06	FINAL FU SYS PRESSURE =	.1034E+06

9 BURNS, CONSTANT ACCELERATION, T/M=0.015

```
   N2O4/MMH, MIN. LENGTH, PUMP FED,                  MR = 2.6

VEHICLE MASS  =27215.5 KG    DELTA V=  4480.6 M/S   AVE. ISP=3141.9 N-S/KG

TOTAL PROPELLANT                          21313.58 KG
  USABLE FUEL                     5743.48
  USABLE OXIDIZER                14933.04
  FUEL TRAPPED                     173.84
  OXID TRAPPED                     448.71
  FUEL START-S/D LOSSES              7.26
  OXID START-S/D LOSSES              7.26

OXIDIZER TANKS (NO.= 1)                     107.62
 (TOROIDAL)
  INNER DIA=     1.817 M
  OUTER DIA=     4.267 M
  HEIGHT   =     1.225 M
  VOLUME   =    11.268 M3
  AVG THK  =    .00081 M
  FS = 1.50,  FNOP= 1.30

FUEL TANKS (NO.= 1)                          41.93
 (ELLIPSOIDAL)
  DIAMETER=     2.683 M
  LENGTH  =     1.897 M
  VOLUME  =     7.149 M3
  AVG THK =    .00064 M
  FS = 1.50,  FNOP= 1.30

PRESSURANT                                   3.366

PRESSURANT TANKS (NO.= 1)                    17.62
  DIA=     .5314 M
  VOL=      .079 M3
  THK=    .00448 M
  FS = 1.50,  FNOP= 1.10


ENGINES (NO.= 1)                             42.18

COMPONENTS AND LINES                        386.01
ENG. MOUNTS,SUPPORTS                       1289.11

TOTAL WET SYSTEM MASS                      23201.4
TOTAL BURNOUT MASS                          2510.4
   (INCL.NON-USABLE PROP. AND GAS)

MASS FRACTION                                 .891
TOTAL IMPULSE                        64966654.5 N-S

             PRESSURE SCHEDULE(N/M2  )   AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =   .2482E+08    INITIAL CHAMBER PRESSURE =0.
INITIAL OX SYS PRESSURE   =   .1379E+06    FINAL OX SYS PRESSURE    =  .1379E+06
INITIAL FU SYS PRESSURE   =   .1034E+06    FINAL FU SYS PRESSURE    =  .1034E+06
```

9 BURNS, CONSTANT ACCELERATION, T/M=0.1

```
  N204/MMH, MIN. LENGTH, PUMP FED,                   MR = 1.8

VEHICLE MASS  =27215.5 KG    DELTA V=  4291.6 M/S   AVE. ISP=3266.4 N-S/KG

TOTAL PROPELLANT                              20526.29 KG
  USABLE FUEL                        7107.13
  USABLE OXIDIZER                   12792.83
  FUEL TRAPPED                        214.14
  OXID TRAPPED                        381.35
  FUEL START-S/D LOSSES                15.42
  OXID START-S/D LOSSES                15.42

OXIDIZER TANKS (NO.= 1)                          93.14
 (TOROIDAL)
  INNER DIA=     2.039 M
  OUTER DIA=     4.267 M
  HEIGHT   =     1.114 M
  VOLUME   =     9.658 M3
  AVG THK  =    .00075 M
  FS = 1.50,  FNOP= 1.30

FUEL TANKS (NO.= 1)                              48.35
 (ELLIPSOIDAL)
  DIAMETER=     2.881 M
  LENGTH  =     2.037 M
  VOLUME  =     8.853 M3
  AVG THK =    .00064 M
  FS = 1.50,  FNOP= 1.30

PRESSURANT                                       3.385

PRESSURANT TANKS (NO.= 1)                        17.73
  DIA=     .5326 M
  VOL=       .079 M3
  THK=    .00449 M
  FS = 1.50,  FNOP= 1.10


ENGINES (NO.= 1)                                100.24

COMPONENTS AND LINES                            386.01
ENG. MOUNTS,SUPPORTS                           1275.05

TOTAL WET SYSTEM MASS                          22450.2
TOTAL BURNOUT MASS                              2519.4
   (INCL.NON-USABLE PROP. AND GAS)

MASS FRACTION                                     .886
TOTAL IMPULSE                              65005073.5 N-S

            PRESSURE SCHEDULE(N/M2  )   AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =   .2482E+08    INITIAL CHAMBER PRESSURE =0.
INITIAL OX SYS PRESSURE   =   .1379E+06    FINAL OX SYS PRESSURE    =  .1379E+06
INITIAL FU SYS PRESSURE   =   .1034E+06    FINAL FU SYS PRESSURE    =  .1034E+06
```

9 BURNS, CONSTANT ACCELERATION, T/M=0.1

```
N2O4/MMH, MIN. LENGTH, PUMP FED,            MR = 2.2

VEHICLE MASS  =27215.5 KG    DELTA V=  4291.6 M/S   AVE. ISP=3288.0 N-S/KG

TOTAL PROPELLANT                             20464.27 KG
  USABLE FUEL                       6198.94
  USABLE OXIDIZER                  13637.68
  FUEL TRAPPED                       186.96
  OXID TRAPPED                       409.85
  FUEL START-S/D LOSSES               15.42
  OXID START-S/D LOSSES               15.42

OXIDIZER TANKS (NO.= 1)                         98.75
 (TOROIDAL)
  INNER DIA=     1.950 M
  OUTER DIA=     4.267 M
  HEIGHT   =     1.159 M
  VOLUME   =    10.297 M3
  AVG THK  =    .00077 M
  FS = 1.50,  FNOP= 1.30

FUEL TANKS (NO.= 1)                             44.15
 (ELLIPSOIDAL)
  DIAMETER=     2.753 M
  LENGTH  =     1.947 M
  VOLUME  =     7.725 M3
  AVG THK =    .00064 M
  FS = 1.50,  FNOP= 1.30

PRESSURANT                                      3.295

PRESSURANT TANKS (NO.= 1)                       17.25
  DIA=     .5277 M
  VOL=      .077 M3
  THK=    .00445 M
  FS = 1.50,  FNOP= 1.10


ENGINES (NO.= 1)                               100.24

COMPONENTS AND LINES                           386.01
ENG. MOUNTS,SUPPORTS                          1275.05

TOTAL WET SYSTEM MASS                         22389.0
TOTAL BURNOUT MASS                             2521.6
   (INCL.NON-USABLE PROP. AND GAS)

MASS FRACTION                                    .886
TOTAL IMPULSE                           65226155.8 N-S

            PRESSURE SCHEDULE(N/M2  )   AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =   .2482E+08    INITIAL CHAMBER PRESSURE =0.
INITIAL OX SYS PRESSURE   =   .1379E+06    FINAL OX SYS PRESSURE    =  .1379E+06
INITIAL FU SYS PRESSURE   =   .1034E+06    FINAL FU SYS PRESSURE    =  .1034E+06
```

9 BURNS, CONSTANT ACCELERATION, T/M=0.1

```
   N204/MMH, MIN. LENGTH, PUMP FED,                MR = 2.6

VEHICLE MASS  =27215.5 KG    DELTA V=  4291.6 M/S   AVE. ISP=3230.2 N-S/KG

TOTAL PROPELLANT                          20639.20 KG
  USABLE FUEL                     5557.53
  USABLE OXIDIZER                14449.59
  FUEL TRAPPED                     167.81
  OXID TRAPPED                     433.42
  FUEL START-S/D LOSSES             15.42
  OXID START-S/D LOSSES             15.42

OXIDIZER TANKS (NO.= 1)                     104.29
 (TOROIDAL)
  INNER DIA=     1.866 M
  OUTER DIA=     4.267 M
  HEIGHT   =     1.201 M
  VOLUME   =    10.909 M3
  AVG THK  =    .00080 M
  FS = 1.50,  FNOP= 1.30

FUEL TANKS (NO.= 1)                          41.06
 (ELLIPSOIDAL)
  DIAMETER=     2.655 M
  LENGTH  =     1.877 M
  VOLUME  =     6.928 M3
  AVG THK =    .00064 M
  FS = 1.50,  FNOP= 1.30

PRESSURANT                                    3.261

PRESSURANT TANKS (NO.= 1)                    17.06
  DIA=     .5257 M
  VOL=      .076 M3
  THK=    .00444 M
  FS = 1.50,  FNOP= 1.10


ENGINES (NO.= 1)                            100.24

COMPONENTS AND LINES                        386.01
ENG. MOUNTS,SUPPORTS                       1275.05

TOTAL WET SYSTEM MASS                     22566.2
TOTAL BURNOUT MASS                         2528.2
   (INCL.NON-USABLE PROP. AND GAS)

MASS FRACTION                                .887
TOTAL IMPULSE                        64629185.2 N-S

             PRESSURE SCHEDULE(N/M2  )   AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =   .2482E+08    INITIAL CHAMBER PRESSURE =0.
INITIAL OX SYS PRESSURE   =   .1379E+06    FINAL OX SYS PRESSURE    =  .1379E+06
INITIAL FU SYS PRESSURE   =   .1034E+06    FINAL FU SYS PRESSURE    =  .1034E+06
```

9 BURNS, CONSTANT ACCELERATION, T/M=0.01

RP-1/LO2, MAX. PERF., PRESSURE FED, MR = 2.8

VEHICLE MASS =27215.5 KG DELTA V= 4815.8 M/S AVE. ISP=3292.9 N-S/KG

TOTAL PROPELLANT		21747.51 KG
USABLE FUEL	5476.39	
USABLE OXIDIZER	15333.90	
FUEL TRAPPED	190.20	
OXID TRAPPED	529.08	
FUEL START-S/D LOSSES	6.80	
OXID START-S/D LOSSES	6.80	
OXIDIZER BOILOFF	204.34	
OXIDIZER TANKS (NO.= 1) (ELLIPSOIDAL)		419.54
DIAMETER= 3.432 M		
LENGTH = 2.427 M		
VOLUME = 14.962 M3		
AVG THK = .00388 M		
FS = 1.50, FNOP= 1.30		
FUEL TANKS (NO.= 1) (ELLIPSOIDAL)		240.70
DIAMETER= 2.713 M		
LENGTH = 1.918 M		
VOLUME = 7.392 M3		
AVG THK = .00357 M		
FS = 1.50, FNOP= 1.30		
PRESSURANT		62.763
PRESSURANT TANKS (NO.= 1)		338.79
DIA= 1.4237 M		
VOL= 1.511 M3		
THK= .01201 M		
FS = 1.50, FNOP= 1.10		
OXIDIZER TANK INSULATION		43.98
ENGINES (NO.= 1)		36.29
COMPONENTS AND LINES		363.33
ENG. MOUNTS,SUPPORTS		1257.81
TOTAL WET SYSTEM MASS		24510.7
TOTAL BURNOUT MASS (INCL.NON-USABLE PROP. AND GAS)		3482.5
MASS FRACTION		.849
TOTAL IMPULSE		68529765.1 N-S

PRESSURE SCHEDULE(N/M2) AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =	.2482E+08	INITIAL CHAMBER PRESSURE =	0.
INITIAL OX SYS PRESSURE =	.1069E+07	FINAL OX SYS PRESSURE =	.1069E+07
INITIAL FU SYS PRESSURE =	.1241E+07	FINAL FU SYS PRESSURE =	.1241E+07

9 BURNS, CONSTANT ACCELERATION, T/M=0.01

RP-1/LO2, MAX. PERF., PRESSURE FED, MR = 3.0

VEHICLE MASS =27215.5 KG DELTA V= 4815.8 M/S AVE. ISP=3265.5 N-S/KG

```
TOTAL PROPELLANT                                21825.99 KG
  USABLE FUEL                        5221.62
  USABLE OXIDIZER                   15664.87
  FUEL TRAPPED                        181.10
  OXID TRAPPED                        539.67
  FUEL START-S/D LOSSES                 6.80
  OXID START-S/D LOSSES                 6.80
  OXIDIZER BOILOFF                    205.12

OXIDIZER TANKS (NO.= 1)                            428.47
 (ELLIPSOIDAL)
  DIAMETER=     3.456 M
  LENGTH  =     2.444 M
  VOLUME  =    15.281 M3
  AVG THK =    .00391 M
  FS = 1.50,  FNOP= 1.30

FUEL TANKS (NO.= 1)                                229.51
 (ELLIPSOIDAL)
  DIAMETER=     2.670 M
  LENGTH  =     1.888 M
  VOLUME  =     7.048 M3
  AVG THK =    .00351 M
  FS = 1.50,  FNOP= 1.30

PRESSURANT                                          63.518

PRESSURANT TANKS (NO.= 1)                          343.06
  DIA=    1.4297 M
  VOL=     1.530 M3
  THK=    .01206 M
  FS = 1.50,  FNOP= 1.10

OXIDIZER TANK INSULATION                            44.60

ENGINES (NO.= 1)                                    36.29

COMPONENTS AND LINES                               363.33
ENG. MOUNTS,SUPPORTS                              1257.81

TOTAL WET SYSTEM MASS                            24592.6
TOTAL BURNOUT MASS                                3487.4
   (INCL.NON-USABLE PROP. AND GAS)

MASS FRACTION                                         .849
TOTAL IMPULSE                                 68207207.6 N-S

            PRESSURE SCHEDULE(N/M2  )   AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =   .2482E+08    INITIAL CHAMBER PRESSURE =0.
INITIAL OX SYS PRESSURE   =   .1069E+07    FINAL OX SYS PRESSURE    =  .1069E+07
INITIAL FU SYS PRESSURE   =   .1241E+07    FINAL FU SYS PRESSURE    =  .1241E+07
```

9 BURNS, CONSTANT ACCELERATION, T/M=0.01

RP-1/LO2, MAX. PERF., PRESSURE FED. MR = 3.2

VEHICLE MASS =27215.5 KG   DELTA V= 4815.8 M/S   AVE. ISP=3234.1 N-S/KG

```
TOTAL PROPELLANT                              21916.55 KG
  USABLE FUEL                       4993.83
  USABLE OXIDIZER                  15980.26
  FUEL TRAPPED                       173.13
  OXID TRAPPED                       549.87
  FUEL START-S/D LOSSES                6.80
  OXID START-S/D LOSSES                6.80
  OXIDIZER BOILOFF                   205.85

OXIDIZER TANKS (NO.= 1)                          436.99
 (ELLIPSOIDAL)
  DIAMETER=     3.479 M
  LENGTH  =     2.460 M
  VOLUME  =    15.584 M3
  AVG THK =    .00394 M
  FS = 1.50,   FNOP= 1.30

FUEL TANKS (NO.= 1)                              219.50
 (ELLIPSOIDAL)
  DIAMETER=     2.631 M
  LENGTH  =     1.860 M
  VOLUME  =     6.741 M3
  AVG THK =    .00346 M
  FS = 1.50,   FNOP= 1.30

PRESSURANT                                        64.261

PRESSURANT TANKS (NO.= 1)                        347.25
  DIA=    1.4355 M
  VOL=     1.549 M3
  THK=    .01211 M
  FS = 1.50,   FNOP= 1.10

OXIDIZER TANK INSULATION                          45.19

ENGINES (NO.= 1)                                  36.29

COMPONENTS AND LINES                             363.33
ENG. MOUNTS,SUPPORTS                            1257.81

TOTAL WET SYSTEM MASS                           24687.2
TOTAL BURNOUT MASS                               3493.6
   (INCL.NON-USABLE PROP. AND GAS)

MASS FRACTION                                      .850
TOTAL IMPULSE                               67835082.0 N-S

             PRESSURE SCHEDULE(N/M2 )  AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =   .2482E+08   INITIAL CHAMBER PRESSURE =0.
INITIAL OX SYS PRESSURE   =   .1069E+07   FINAL OX SYS PRESSURE    =  .1069E+07
INITIAL FU SYS PRESSURE   =   .1241E+07   FINAL FU SYS PRESSURE    =  .1241E+07
```

9 BURNS, CONSTANT ACCELERATION, T/M=0.015

```
     RP-1/LO2, MAX. PERF., PRESSURE FED,                 MR = 2.8

VEHICLE MASS  =27215.5 KG    DELTA V=  4480.6 M/S   AVE. ISP=3309.6 N-S/KG

TOTAL PROPELLANT                          21000.81 KG
  USABLE FUEL                  5287.03
  USABLE OXIDIZER             14803.69
  FUEL TRAPPED                  183.11
  OXID TRAPPED                  509.38
  FUEL START-S/D LOSSES           7.26
  OXID START-S/D LOSSES           7.26
  OXIDIZER BOILOFF              203.08

OXIDIZER TANKS (NO.= 1)                     405.16
 (ELLIPSOIDAL)
  DIAMETER=     3.392 M
  LENGTH   =    2.399 M
  VOLUME   =   14.449 M3
  AVG THK =    .00384 M
  FS = 1.50,   FNOP= 1.30

FUEL TANKS (NO.= 1)                         232.39
 (ELLIPSOIDAL)
  DIAMETER=     2.681 M
  LENGTH   =    1.896 M
  VOLUME   =    7.137 M3
  AVG THK =    .00352 M
  FS = 1.50,   FNOP= 1.30

PRESSURANT                                  60.611

PRESSURANT TANKS (NO.= 1)                   327.18
  DIA=    1.4073 M
  VOL=     1.459 M3
  THK=    .01187 M
  FS = 1.50,   FNOP= 1.10

OXIDIZER TANK INSULATION                     42.97

ENGINES (NO.= 1)                             49.90

COMPONENTS AND LINES                        363.33
ENG. MOUNTS,SUPPORTS                       1250.55

TOTAL WET SYSTEM MASS                      23732.9
TOTAL BURNOUT MASS                          3424.6
   (INCL.NON-USABLE PROP. AND GAS)

MASS FRACTION                                 .847
TOTAL IMPULSE                           66495127.3 N-S

             PRESSURE SCHEDULE(N/M2  )    AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =    .2482E+08    INITIAL CHAMBER PRESSURE =0.
INITIAL OX SYS PRESSURE   =    .1069E+07    FINAL OX SYS PRESSURE    =   .1069E+07
INITIAL FU SYS PRESSURE   =    .1241E+07    FINAL FU SYS PRESSURE    =   .1241E+07
```

9 BURNS, CONSTANT ACCELERATION, T/M=0.015

```
    RP-1/LO2, MAX. PERF., PRESSURE FED,                      MR = 3.0

VEHICLE MASS  =27215.5 KG    DELTA V=  4480.6 M/S   AVE. ISP=3284.1 N-S/KG

TOTAL PROPELLANT                                21076.56 KG
  USABLE FUEL                         5040.85
  USABLE OXIDIZER                    15122.55
  FUEL TRAPPED                         174.68
  OXID TRAPPED                         520.12
  FUEL START-S/D LOSSES                  7.26
  OXID START-S/D LOSSES                  7.26
  OXIDIZER BOILOFF                     203.84

OXIDIZER TANKS (NO.= 1)                           413.79
 (ELLIPSOIDAL)
  DIAMETER=     3.416 M
  LENGTH  =     2.415 M
  VOLUME  =    14.757 M3
  AVG THK =    .00387 M
  FS = 1.50,   FNOP= 1.30

FUEL TANKS (NO.= 1)                               221.58
 (ELLIPSOIDAL)
  DIAMETER=     2.639 M
  LENGTH  =     1.866 M
  VOLUME  =     6.805 M3
  AVG THK =    .00347 M
  FS = 1.50,   FNOP= 1.30

PRESSURANT                                         61.337

PRESSURANT TANKS (NO.= 1)                         331.28
  DIA=    1.4131 M
  VOL=     1.478 M3
  THK=    .01192 M
  FS = 1.50,   FNOP= 1.10

OXIDIZER TANK INSULATION                           43.58

ENGINES (NO.= 1)                                   49.90

COMPONENTS AND LINES                              363.33
ENG. MOUNTS,SUPPORTS                             1250.55

TOTAL WET SYSTEM MASS                           23811.9
TOTAL BURNOUT MASS                               3430.1
   (INCL.NON-USABLE PROP. AND GAS)

MASS FRACTION                                        .847
TOTAL IMPULSE                              66221580.4 N-S

             PRESSURE SCHEDULE(N/M2   )    AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =    .2482E+08    INITIAL CHAMBER PRESSURE =0.
INITIAL OX SYS PRESSURE   =    .1069E+07    FINAL OX SYS PRESSURE    =   .1069E+07
INITIAL FU SYS PRESSURE   =    .1241E+07    FINAL FU SYS PRESSURE    =   .1241E+07
```

9 BURNS, CONSTANT ACCELERATION, T/M=0.015

```
     RP-1/LO2, MAX. PERF., PRESSURE FED,                MR = 3.2

VEHICLE MASS  =27215.5 KG    DELTA V=  4480.6 M/S   AVE. ISP=3253.7 N-S/KG

TOTAL PROPELLANT                              21166.75 KG
  USABLE FUEL                        4821.58
  USABLE OXIDIZER                   15429.06
  FUEL TRAPPED                        166.93
  OXID TRAPPED                        530.10
  FUEL START-S/D LOSSES                 7.26
  OXID START-S/D LOSSES                 7.26
  OXIDIZER BOILOFF                    204.56

OXIDIZER TANKS (NO.= 1)                         422.07
 (ELLIPSOIDAL)
  DIAMETER=     3.439 M
  LENGTH  =     2.431 M
  VOLUME  =    15.052 M3
  AVG THK =    .00389 M
  FS = 1.50,  FNOP= 1.30

FUEL TANKS (NO.= 1)                             211.95
 (ELLIPSOIDAL)
  DIAMETER=     2.600 M
  LENGTH  =     1.839 M
  VOLUME  =     6.509 M3
  AVG THK =    .00342 M
  FS = 1.50,  FNOP= 1.30

PRESSURANT                                      62.062

PRESSURANT TANKS (NO.= 1)                       335.37
  DIA=    1.4189 M
  VOL=     1.496 M3
  THK=    .01197 M
  FS = 1.50,  FNOP= 1.10

OXIDIZER TANK INSULATION                         44.16

ENGINES (NO.= 1)                                 49.90

COMPONENTS AND LINES                            363.33
ENG. MOUNTS,SUPPORTS                           1250.55

TOTAL WET SYSTEM MASS                          23906.1
TOTAL BURNOUT MASS                              3436.4
   (INCL.NON-USABLE PROP. AND GAS)

MASS FRACTION                                     .847
TOTAL IMPULSE                              65892462.3 N-S

             PRESSURE SCHEDULE(N/M2  )   AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =   .2482E+08    INITIAL CHAMBER PRESSURE =0.
INITIAL OX SYS PRESSURE   =   .1069E+07    FINAL OX SYS PRESSURE    =  .1069E+07
INITIAL FU SYS PRESSURE   =   .1241E+07    FINAL FU SYS PRESSURE    =  .1241E+07
```

9 BURNS, CONSTANT ACCELERATION, T/M=0.1

RP-1/LO2, MAX. PERF., PRESSURE FED, MR = 2.8

VEHICLE MASS =27215.5 KG DELTA V= 4291.6 M/S AVE. ISP=3384.1 N-S/KG

TOTAL PROPELLANT		20364.02 KG
USABLE FUEL	5122.57	
USABLE OXIDIZER	14343.19	
FUEL TRAPPED	175.78	
OXID TRAPPED	489.65	
FUEL START-S/D LOSSES	15.42	
OXID START-S/D LOSSES	15.42	
OXIDIZER BOILOFF	201.99	
OXIDIZER TANKS (NO.= 1)		392.81
(ELLIPSOIDAL)		
DIAMETER= 3.357 M		
LENGTH = 2.374 M		
VOLUME = 14.009 M3		
AVG THK = .00380 M		
FS = 1.50, FNOP= 1.30		
FUEL TANKS (NO.= 1)		225.44
(ELLIPSOIDAL)		
DIAMETER= 2.654 M		
LENGTH = 1.877 M		
VOLUME = 6.923 M3		
AVG THK = .00349 M		
FS = 1.50, FNOP= 1.30		
PRESSURANT		58.771
PRESSURANT TANKS (NO.= 1)		317.24
DIA= 1.3929 M		
VOL= 1.415 M3		
THK= .01175 M		
FS = 1.50, FNOP= 1.10		
OXIDIZER TANK INSULATION		42.09
ENGINES (NO.= 1)		235.87
COMPONENTS AND LINES		363.33
ENG. MOUNTS, SUPPORTS		1241.94
TOTAL WET SYSTEM MASS		23241.5
TOTAL BURNOUT MASS		3542.9
(INCL.NON-USABLE PROP. AND GAS)		
MASS FRACTION		.838
TOTAL IMPULSE		65877441.4 N-S

PRESSURE SCHEDULE(N/M2) AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =	.2482E+08	INITIAL CHAMBER PRESSURE =	0.
INITIAL OX SYS PRESSURE =	.1069E+07	FINAL OX SYS PRESSURE =	.1069E+07
INITIAL FU SYS PRESSURE =	.1241E+07	FINAL FU SYS PRESSURE =	.1241E+07

9 BURNS, CONSTANT ACCELERATION, T/M=0.1

RP-1/LO2, MAX. PERF., PRESSURE FED, MR = 3.0

VEHICLE MASS =27215.5 KG DELTA V= 4291.6 M/S AVE. ISP=3357.6 N-S/KG

TOTAL PROPELLANT		20442.55 KG
USABLE FUEL	4885.29	
USABLE OXIDIZER	14655.86	
FUEL TRAPPED	168.03	
OXID TRAPPED	499.78	
FUEL START-S/D LOSSES	15.42	
OXID START-S/D LOSSES	15.42	
OXIDIZER BOILOFF	202.74	

OXIDIZER TANKS (NO.= 1) 401.26
(ELLIPSOIDAL)
DIAMETER= 3.381 M
LENGTH = 2.391 M
VOLUME = 14.310 M3
AVG THK = .00383 M
FS = 1.50, FNOP= 1.30

FUEL TANKS (NO.= 1) 215.05
(ELLIPSOIDAL)
DIAMETER= 2.613 M
LENGTH = 1.848 M
VOLUME = 6.604 M3
AVG THK = .00343 M
FS = 1.50, FNOP= 1.30

PRESSURANT 59.490

PRESSURANT TANKS (NO.= 1) 321.30
DIA= 1.3988 M
VOL= 1.433 M3
THK= .01180 M
FS = 1.50, FNOP= 1.10

OXIDIZER TANK INSULATION 42.69

ENGINES (NO.= 1) 235.87

COMPONENTS AND LINES 363.33
ENG. MOUNTS, SUPPORTS 1241.94

TOTAL WET SYSTEM MASS 23323.5
TOTAL BURNOUT MASS 3548.7
(INCL.NON-USABLE PROP. AND GAS)

MASS FRACTION .838
TOTAL IMPULSE 65615194.2 N-S

PRESSURE SCHEDULE(N/M2) AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =	.2482E+08	INITIAL CHAMBER PRESSURE =	0.
INITIAL OX SYS PRESSURE =	.1069E+07	FINAL OX SYS PRESSURE =	.1069E+07
INITIAL FU SYS PRESSURE =	.1241E+07	FINAL FU SYS PRESSURE =	.1241E+07

9 BURNS, CONSTANT ACCELERATION, T/M=0.1

RP-1/LO2, MAX. PERF., PRESSURE FED, MR = 3.2

VEHICLE MASS =27215.5 KG DELTA V= 4291.6 M/S AVE. ISP=3327.2 N-S/KG

TOTAL PROPELLANT		20532.20 KG
USABLE FUEL	4673.41	
USABLE OXIDIZER	14954.92	
FUEL TRAPPED	160.46	
OXID TRAPPED	509.12	
FUEL START-S/D LOSSES	15.42	
OXID START-S/D LOSSES	15.42	
OXIDIZER BOILOFF	203.45	
OXIDIZER TANKS (NO.= 1) (ELLIPSOIDAL) DIAMETER= 3.404 M, LENGTH = 2.407 M, VOLUME = 14.598 M3, AVG THK = .00385 M, FS = 1.50, FNOP= 1.30		409.33
FUEL TANKS (NO.= 1) (ELLIPSOIDAL) DIAMETER= 2.575 M, LENGTH = 1.820 M, VOLUME = 6.318 M3, AVG THK = .00338 M, FS = 1.50, FNOP= 1.30		205.74
PRESSURANT		60.200
PRESSURANT TANKS (NO.= 1) DIA= 1.4046 M, VOL= 1.451 M3, THK= .01185 M, FS = 1.50, FNOP= 1.10		325.30
OXIDIZER TANK INSULATION		43.26
ENGINES (NO.= 1)		235.87
COMPONENTS AND LINES		363.33
ENG. MOUNTS, SUPPORTS		1241.94
TOTAL WET SYSTEM MASS		23417.2
TOTAL BURNOUT MASS (INCL.NON-USABLE PROP. AND GAS)		3554.5
MASS FRACTION		.838
TOTAL IMPULSE		65311223.9 N-S

PRESSURE SCHEDULE(N/M2) AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =	.2482E+08	INITIAL CHAMBER PRESSURE =	0.
INITIAL OX SYS PRESSURE =	.1069E+07	FINAL OX SYS PRESSURE =	.1069E+07
INITIAL FU SYS PRESSURE =	.1241E+07	FINAL FU SYS PRESSURE =	.1241E+07

9 BURNS, CONSTANT ACCELERATION, T/M=0.01

RP-1/LO2, MIN. LENGTH, PRESSURE FED,   MR = 2.8

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VEHICLE MASS   =27215.5 KG     DELTA V=  4815.8 M/S    AVE. ISP=3292.9 N-S/KG

TOTAL PROPELLANT                            21769.83 KG
  USABLE FUEL                      5473.24
  USABLE OXIDIZER                 15325.07
  FUEL TRAPPED                      194.30
  OXID TRAPPED                      539.89
  FUEL START-S/D LOSSES               6.80
  OXID START-S/D LOSSES               6.80
  OXIDIZER BOILOFF                  223.72

OXIDIZER TANKS (NO.= 1)                       556.71
 (TOROIDAL)
  INNER DIA=     1.318 M
  OUTER DIA=     4.267 M
  HEIGHT   =     1.475 M
  VOLUME   =    14.982 M3
  AVG THK  =    .00330 M
  FS = 1.50,  FNOP= 1.50

FUEL TANKS (NO.= 1)                           240.74
 (ELLIPSOIDAL)
  DIAMETER=     2.713 M
  LENGTH  =   ' 1.918 M
  VOLUME  =     7.393 M3
  AVG THK =    .00357 M
  FS = 1.50,  FNOP= 1.30

PRESSURANT                                    62.780

PRESSURANT TANKS (NO.= 1)                     338.88
  DIA=    1.4239 M
  VOL=     1.511 M3
  THK=    .01201 M
  FS = 1.50,  FNOP= 1.10

OXIDIZER TANK INSULATION                       59.53

ENGINES (NO.= 1)                               36.29

COMPONENTS AND LINES                          386.01
ENG. MOUNTS,SUPPORTS                         1253.28

TOTAL WET SYSTEM MASS                        24704.0
TOTAL BURNOUT MASS                            3668.4
   (INCL.NON-USABLE PROP. AND GAS)

MASS FRACTION                                   .842
TOTAL IMPULSE                           68490307.5 N-S

             PRESSURE SCHEDULE(N/M2  )  AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =   .2482E+08    INITIAL CHAMBER PRESSURE =0.
INITIAL OX SYS PRESSURE   =   .1069E+07    FINAL OX SYS PRESSURE    =  .1069E+07
INITIAL FU SYS PRESSURE   =   .1241E+07    FINAL FU SYS PRESSURE    =  .1241E+07
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9 BURNS, CONSTANT ACCELERATION, T/M=0.01

RP-1/LO2, MIN. LENGTH, PRESSURE FED,   MR = 3.0

VEHICLE MASS =27215.5 KG   DELTA V= 4815.8 M/S   AVE. ISP=3265.5 N-S/KG

TOTAL PROPELLANT		21848.61 KG
USABLE FUEL	5218.66	
USABLE OXIDIZER	15655.98	
FUEL TRAPPED	185.20	
OXID TRAPPED	550.94	
FUEL START-S/D LOSSES	6.80	
OXID START-S/D LOSSES	6.80	
OXIDIZER BOILOFF	224.22	
OXIDIZER TANKS (NO.= 1)		574.40
(TOROIDAL)		
INNER DIA= 1.275 M		
OUTER DIA= 4.267 M		
HEIGHT = 1.496 M		
VOLUME = 15.301 M3		
AVG THK = .00338 M		
FS = 1.50, FNOP= 1.50		
FUEL TANKS (NO.= 1)		229.55
(ELLIPSOIDAL)		
DIAMETER= 2.670 M		
LENGTH = 1.888 M		
VOLUME = 7.050 M3		
AVG THK = .00351 M		
FS = 1.50, FNOP= 1.30		
PRESSURANT		63.534
PRESSURANT TANKS (NO.= 1)		343.14
DIA= 1.4298 M		
VOL= 1.530 M3		
THK= .01206 M		
FS = 1.50, FNOP= 1.10		
OXIDIZER TANK INSULATION		59.93
ENGINES (NO.= 1)		36.29
COMPONENTS AND LINES		386.01
ENG. MOUNTS, SUPPORTS		1253.28
TOTAL WET SYSTEM MASS		24794.7
TOTAL BURNOUT MASS		3682.3
(INCL.NON-USABLE PROP. AND GAS)		
MASS FRACTION		.842
TOTAL IMPULSE		68168496.7 N-S

PRESSURE SCHEDULE(N/M2)   AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =	.2482E+08	INITIAL CHAMBER PRESSURE =	0.
INITIAL OX SYS PRESSURE =	.1069E+07	FINAL OX SYS PRESSURE =	.1069E+07
INITIAL FU SYS PRESSURE =	.1241E+07	FINAL FU SYS PRESSURE =	.1241E+07

9 BURNS, CONSTANT ACCELERATION, T/M=0.01

RP-1/LO2, MIN. LENGTH, PRESSURE FED, MR = 3.2

VEHICLE MASS =27215.5 KG DELTA V= 4815.8 M/S AVE. ISP=3234.1 N-S/KG

TOTAL PROPELLANT		21939.02 KG
USABLE FUEL	4991.04	
USABLE OXIDIZER	15971.32	
FUEL TRAPPED	176.78	
OXID TRAPPED	561.59	
FUEL START-S/D LOSSES	6.80	
OXID START-S/D LOSSES	6.80	
OXIDIZER BOILOFF	224.68	
OXIDIZER TANKS (NO.= 1)		591.93
(TOROIDAL)		
INNER DIA= 1.235 M		
OUTER DIA= 4.267 M		
HEIGHT = 1.516 M		
VOLUME = 15.605 M3		
AVG THK = .00346 M		
FS = 1.50, FNOP= 1.50		
FUEL TANKS (NO.= 1)		219.54
(ELLIPSOIDAL)		
DIAMETER= 2.631 M		
LENGTH = 1.860 M		
VOLUME = 6.742 M3		
AVG THK = .00346 M		
FS = 1.50, FNOP= 1.30		
PRESSURANT		64.276
PRESSURANT TANKS (NO.= 1)		347.33
DIA= 1.4356 M		
VOL= 1.549 M3		
THK= .01211 M		
FS = 1.50, FNOP= 1.10		
OXIDIZER TANK INSULATION		60.30
ENGINES (NO.= 1)		36.29
COMPONENTS AND LINES		386.01
ENG. MOUNTS, SUPPORTS		1253.28
TOTAL WET SYSTEM MASS		24898.0
TOTAL BURNOUT MASS		3697.3
(INCL.NON-USABLE PROP. AND GAS)		
MASS FRACTION		.842
TOTAL IMPULSE		67797133.2 N-S

PRESSURE SCHEDULE(N/M2) AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =	.2482E+08	INITIAL CHAMBER PRESSURE =	0.
INITIAL OX SYS PRESSURE =	.1069E+07	FINAL OX SYS PRESSURE =	.1069E+07
INITIAL FU SYS PRESSURE =	.1241E+07	FINAL FU SYS PRESSURE =	.1241E+07

9 BURNS, CONSTANT ACCELERATION, T/M=0.015

RP-1/LO2, MIN. LENGTH, PRESSURE FED, MR = 2.8

VEHICLE MASS =27215.5 KG DELTA V= 4480.6 M/S AVE. ISP=3309.6 N-S/KG

TOTAL PROPELLANT		21024.17 KG
USABLE FUEL	5283.92	
USABLE OXIDIZER	14794.98	
FUEL TRAPPED	187.21	
OXID TRAPPED	520.66	
FUEL START-S/D LOSSES	7.26	
OXID START-S/D LOSSES	7.26	
OXIDIZER BOILOFF	222.89	
OXIDIZER TANKS (NO.= 1)		529.60
(TOROIDAL)		
INNER DIA= 1.387 M		
OUTER DIA= 4.267 M		
HEIGHT = 1.440 M		
VOLUME = 14.470 M3		
AVG THK = .00317 M		
FS = 1.50, FNOP= 1.50		
FUEL TANKS (NO.= 1)		232.43
(ELLIPSOIDAL)		
DIAMETER= 2.681 M		
LENGTH = 1.896 M		
VOLUME = 7.138 M3		
AVG THK = .00352 M		
FS = 1.50, FNOP= 1.30		
PRESSURANT		60.629
PRESSURANT TANKS (NO.= 1)		327.27
DIA= 1.4074 M		
VOL= 1.460 M3		
THK= .01188 M		
FS = 1.50, FNOP= 1.10		
OXIDIZER TANK INSULATION		58.86
ENGINES (NO.= 1)		49.90
COMPONENTS AND LINES		386.01
ENG. MOUNTS, SUPPORTS		1243.30
TOTAL WET SYSTEM MASS		23912.2
TOTAL BURNOUT MASS		3595.9
(INCL.NON-USABLE PROP. AND GAS)		
MASS FRACTION		.840
TOTAL IMPULSE		66456000.6 N-S

PRESSURE SCHEDULE(N/M2) AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =	.2482E+08	INITIAL CHAMBER PRESSURE =	0.
INITIAL OX SYS PRESSURE =	.1069E+07	FINAL OX SYS PRESSURE =	.1069E+07
INITIAL FU SYS PRESSURE =	.1241E+07	FINAL FU SYS PRESSURE =	.1241E+07

9 BURNS, CONSTANT ACCELERATION, T/M=0.015

RP-1/LO2. MIN. LENGTH. PRESSURE FED.   MR = 3.0

VEHICLE MASS =27215.5 KG   DELTA V= 4480.6 M/S   AVE. ISP=3284.1 N-S/KG

TOTAL PROPELLANT		21099.33 KG
USABLE FUEL	5037.92	
USABLE OXIDIZER	15113.77	
FUEL TRAPPED	178.33	
OXID TRAPPED	531.40	
FUEL START-S/D LOSSES	7.26	
OXID START-S/D LOSSES	7.26	
OXIDIZER BOILOFF	223.39	
OXIDIZER TANKS (NO.= 1)		545.69
(TOROIDAL)		
INNER DIA= 1.345 M		
OUTER DIA= 4.267 M		
HEIGHT = 1.461 M		
VOLUME = 14.777 M3		
AVG THK = .00325 M		
FS = 1.50, FNOP= 1.50		
FUEL TANKS (NO.= 1)		221.61
(ELLIPSOIDAL)		
DIAMETER= 2.639 M		
LENGTH = 1.866 M		
VOLUME = 6.806 M3		
AVG THK = .00347 M		
FS = 1.50, FNOP= 1.30		
PRESSURANT		61.354
PRESSURANT TANKS (NO.= 1)		331.37
DIA= 1.4133 M		
VOL= 1.478 M3		
THK= .01192 M		
FS = 1.50, FNOP= 1.10		
OXIDIZER TANK INSULATION		59.27
ENGINES (NO.= 1)		49.90
COMPONENTS AND LINES		386.01
ENG. MOUNTS,SUPPORTS		1243.30
TOTAL WET SYSTEM MASS		23997.8
TOTAL BURNOUT MASS		3608.2
(INCL.NON-USABLE PROP. AND GAS)		
MASS FRACTION		.840
TOTAL IMPULSE		66183109.8 N-S

PRESSURE SCHEDULE(N/M2) AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =	.2482E+08	INITIAL CHAMBER PRESSURE =	0.
INITIAL OX SYS PRESSURE =	.1069E+07	FINAL OX SYS PRESSURE =	.1069E+07
INITIAL FU SYS PRESSURE =	.1241E+07	FINAL FU SYS PRESSURE =	.1241E+07

9 BURNS, CONSTANT ACCELERATION, T/M=0.015

RP-1/LO2, MIN. LENGTH, PRESSURE FED, MR = 3.2

VEHICLE MASS =27215.5 KG DELTA V= 4480.6 M/S AVE. ISP=3253.7 N-S/KG

TOTAL PROPELLANT		21189.36 KG
USABLE FUEL	4818.82	
USABLE OXIDIZER	15420.21	
FUEL TRAPPED	170.57	
OXID TRAPPED	541.37	
FUEL START-S/D LOSSES	7.26	
OXID START-S/D LOSSES	7.26	
OXIDIZER BOILOFF	223.86	
OXIDIZER TANKS (NO.= 1)		561.66
(TOROIDAL)		
INNER DIA= 1.306 M		
OUTER DIA= 4.267 M		
HEIGHT = 1.481 M		
VOLUME = 15.072 M3		
AVG THK = .00332 M		
FS = 1.50, FNOP= 1.50		
FUEL TANKS (NO.= 1)		211.99
(ELLIPSOIDAL)		
DIAMETER= 2.600 M		
LENGTH = 1.839 M		
VOLUME = 6.510 M3		
AVG THK = .00342 M		
FS = 1.50, FNOP= 1.30		
PRESSURANT		62.079
PRESSURANT TANKS (NO.= 1)		335.45
DIA= 1.4190 M		
VOL= 1.496 M3		
THK= .01197 M		
FS = 1.50, FNOP= 1.10		
OXIDIZER TANK INSULATION		59.64
ENGINES (NO.= 1)		49.90
COMPONENTS AND LINES		386.01
ENG. MOUNTS,SUPPORTS		1243.30
TOTAL WET SYSTEM MASS		24099.4
TOTAL BURNOUT MASS		3622.0
(INCL.NON-USABLE PROP. AND GAS)		
MASS FRACTION		.840
TOTAL IMPULSE		65854673.5 N-S

PRESSURE SCHEDULE(N/M2) AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =	.2482E+08	INITIAL CHAMBER PRESSURE =	0.
INITIAL OX SYS PRESSURE =	.1069E+07	FINAL OX SYS PRESSURE =	.1069E+07
INITIAL FU SYS PRESSURE =	.1241E+07	FINAL FU SYS PRESSURE =	.1241E+07

9 BURNS, CONSTANT ACCELERATION, T/M=0.1

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   RP-1/LO2, MIN. LENGTH, PRESSURE FED,                  MR = 2.8

VEHICLE MASS  =27215.5 KG    DELTA V=  4291.6 M/S   AVE. ISP=3384.1 N-S/KG

TOTAL PROPELLANT                            20407.51 KG
  USABLE FUEL                     5119.50
  USABLE OXIDIZER                14334.59
  FUEL TRAPPED                     185.35
  OXID TRAPPED                     515.07
  FUEL START-S/D LOSSES             15.42
  OXID START-S/D LOSSES             15.42
  OXIDIZER BOILOFF                 222.16

OXIDIZER TANKS (NO.= 1)                       508.07
 (TOROIDAL)
  INNER DIA=     1.444 M
  OUTER DIA=     4.267 M
  HEIGHT   =     1.412 M
  VOLUME   =    14.043 M3
  AVG THK  =    .00308 M
  FS = 1.50,  FNOP= 1.50

FUEL TANKS (NO.= 1)                           225.72
 (ELLIPSOIDAL)
  DIAMETER=     2.655 M
  LENGTH  =     1.878 M
  VOLUME  =     6.932 M3
  AVG THK =    .00349 M
  FS = 1.50,  FNOP= 1.30

PRESSURANT                                     58.793

PRESSURANT TANKS (NO.= 1)                     317.35
  DIA=    1.3930 M
  VOL=      1.415 M3
  THK=    .01175 M
  FS = 1.50,  FNOP= 1.10

OXIDIZER TANK INSULATION                       58.28

ENGINES (NO.= 1)                              235.87

COMPONENTS AND LINES                          386.01
ENG. MOUNTS,SUPPORTS                         1231.50

TOTAL WET SYSTEM MASS                        23429.1
TOTAL BURNOUT MASS                            3722.0
   (INCL.NON-USABLE PROP. AND GAS)

MASS FRACTION                                   .830
TOTAL IMPULSE                            65837960.7 N-S

             PRESSURE SCHEDULE(N/M2  )   AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =   .2482E+08   INITIAL CHAMBER PRESSURE =0.
INITIAL OX SYS PRESSURE   =   .1069E+07   FINAL OX SYS PRESSURE    =  .1069E+07
INITIAL FU SYS PRESSURE   =   .1241E+07   FINAL FU SYS PRESSURE    =  .1241E+07
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9 BURNS, CONSTANT ACCELERATION, T/M=0.1

RP-1/LO2, MIN. LENGTH, PRESSURE FED,   MR = 3.0

VEHICLE MASS =27215.5 KG   DELTA V= 4291.6 M/S   AVE. ISP=3357.6 N-S/KG

.TOTAL PROPELLANT		20485.89 KG
USABLE FUEL	4882.39	
USABLE OXIDIZER	14647.18	
FUEL TRAPPED	176.69	
OXID TRAPPED	526.11	
FUEL START-S/D LOSSES	15.42	
OXID START-S/D LOSSES	15.42	
OXIDIZER BOILOFF	222.68	

OXIDIZER TANKS (NO.= 1)   523.20
(TOROIDAL)
INNER DIA= 1.403 M
OUTER DIA= 4.267 M
HEIGHT = 1.432 M
VOLUME = 14.345 M3
AVG THK = .00314 M
FS = 1.50, FNOP= 1.50

FUEL TANKS (NO.= 1)   215.29
(ELLIPSOIDAL)
DIAMETER= 2.614 M
LENGTH = 1.848 M
VOLUME = 6.612 M3
AVG THK = .00344 M
FS = 1.50, FNOP= 1.30

PRESSURANT   59.510

PRESSURANT TANKS (NO.= 1)   321.40
DIA= 1.3989 M
VOL= 1.434 M3
THK= .01180 M
FS = 1.50, FNOP= 1.10

OXIDIZER TANK INSULATION   58.69

ENGINES (NO.= 1)   235.87

COMPONENTS AND LINES   386.01
ENG. MOUNTS,SUPPORTS   1231.50

TOTAL WET SYSTEM MASS   23517.4
TOTAL BURNOUT MASS   3734.3
(INCL.NON-USABLE PROP. AND GAS)

MASS FRACTION   .830
TOTAL IMPULSE   65576323.1 N-S

PRESSURE SCHEDULE(N/M2) AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =	.2482E+08	INITIAL CHAMBER PRESSURE =	0.
INITIAL OX SYS PRESSURE =	.1069E+07	FINAL OX SYS PRESSURE =	.1069E+07
INITIAL FU SYS PRESSURE =	.1241E+07	FINAL FU SYS PRESSURE =	.1241E+07

9 BURNS, CONSTANT ACCELERATION, T/M=0.1

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   RP-1/LO2, MIN. LENGTH, PRESSURE FED,              MR = 3.2

VEHICLE MASS  =27215.5 KG    DELTA V=  4291.6 M/S   AVE. ISP=3327.2 N-S/KG

TOTAL PROPELLANT                          20575.40 KG
  USABLE FUEL                    4670.68
  USABLE OXIDIZER               14946.17
  FUEL TRAPPED                    168.66
  OXID TRAPPED                    535.89
  FUEL START-S/D LOSSES            15.42
  OXID START-S/D LOSSES            15.42
  OXIDIZER BOILOFF                223.16

OXIDIZER TANKS (NO.= 1)                     538.06
 (TOROIDAL)
  INNER DIA=     1.365 M
  OUTER DIA=     4.267 M
  HEIGHT   =     1.451 M
  VOLUME   =    14.633 M3
  AVG THK  =    .00321 M
  FS = 1.50,  FNOP= 1.50

FUEL TANKS (NO.= 1)                         205.97
 (ELLIPSOIDAL)
  DIAMETER=     2.576 M
  LENGTH  =     1.821 M
  VOLUME  =     6.325 M3
  AVG THK =    .00338 M
  FS = 1.50,  FNOP= 1.30

PRESSURANT                                  60.221

PRESSURANT TANKS (NO.= 1)                   325.40
  DIA=    1.4047 M
  VOL=     1.451 M3
  THK=    .01185 M
  FS = 1.50,  FNOP= 1.10

OXIDIZER TANK INSULATION                     59.08

ENGINES (NO.= 1)                            235.87

COMPONENTS AND LINES                        386.01
ENG. MOUNTS,SUPPORTS                       1231.50

TOTAL WET SYSTEM MASS                      23617.5
TOTAL BURNOUT MASS                          3746.7
   (INCL.NON-USABLE PROP. AND GAS)

MASS FRACTION                                 .831
TOTAL IMPULSE                           65272981.2 N-S

             PRESSURE SCHEDULE(N/M2  )   AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =   .2482E+08    INITIAL CHAMBER PRESSURE =0.
INITIAL OX SYS PRESSURE   =   .1069E+07    FINAL OX SYS PRESSURE    =  .1069E+07
INITIAL FU SYS PRESSURE   =   .1241E+07    FINAL FU SYS PRESSURE    =  .1241E+07
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9 BURNS, CONSTANT ACCELERATION, T/M=0.01

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RP-1/LO2, MAX. PERF., PUMP FED,            MR = 2.8

VEHICLE MASS  =27215.5 KG    DELTA V=  4815.8 M/S   AVE. ISP=3334.1 N-S/KG

TOTAL PROPELLANT                              21630.17 KG
  USABLE FUEL                       5446.32
  USABLE OXIDIZER                  15249.70
  FUEL TRAPPED                       189.43
  OXID TRAPPED                       526.96
  FUEL START-S/D LOSSES                6.80
  OXID START-S/D LOSSES                6.80
  OXIDIZER BOILOFF                   204.14

OXIDIZER TANKS (NO.= 1)                          68.35
 (ELLIPSOIDAL)
  DIAMETER=     3.425 M
  LENGTH  =     2.422 M
  VOLUME  =    14.882 M3
  AVG THK =    .00064 M
  FS = 1.50,  FNOP= 1.30

FUEL TANKS (NO.= 1)                              42.72
 (ELLIPSOIDAL)
  DIAMETER=     2.708 M
  LENGTH  =     1.915 M
  VOLUME  =     7.352 M3
  AVG THK =    .00064 M
  FS = 1.50,  FNOP= 1.30

PRESSURANT                                       4.926

PRESSURANT TANKS (NO.= 1)                        26.31
  DIA=     .6074 M
  VOL=      .117 M3
  THK=    .00513 M
  FS = 1.50,  FNOP= 1.10

OXIDIZER TANK INSULATION                         43.82

ENGINES (NO.= 1)                                 37.65

COMPONENTS AND LINES                            363.33
ENG. MOUNTS,SUPPORTS                           1260.08

TOTAL WET SYSTEM MASS                          23477.3
TOTAL BURNOUT MASS                              2563.6
   (INCL.NON-USABLE PROP. AND GAS)

MASS FRACTION                                     .882
TOTAL IMPULSE                             69005898.5 N-S

            PRESSURE SCHEDULE(N/M2  )    AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =   .2482E+08   INITIAL CHAMBER PRESSURE =0.
INITIAL OX SYS PRESSURE   =   .1517E+06   FINAL OX SYS PRESSURE    =  .1517E+06
INITIAL FU SYS PRESSURE   =   .1034E+06   FINAL FU SYS PRESSURE    =  .1034E+06
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9 BURNS, CONSTANT ACCELERATION, T/M=0.01

RP-1/LO2, MAX. PERF., PUMP FED, MR = 3.0

VEHICLE MASS =27215.5 KG DELTA V= 4815.8 M/S AVE. ISP=3304.7 N-S/KG

TOTAL PROPELLANT		21713.71 KG
USABLE FUEL	5194.29	
USABLE OXIDIZER	15582.87	
FUEL TRAPPED	180.41	
OXID TRAPPED	537.61	
FUEL START-S/D LOSSES	6.80	
OXID START-S/D LOSSES	6.80	
OXIDIZER BOILOFF	204.92	
OXIDIZER TANKS (NO.= 1) (ELLIPSOIDAL)		69.33
DIAMETER= 3.450 M		
LENGTH = 2.439 M		
VOLUME = 15.202 M3		
AVG THK = .00064 M		
FS = 1.50, FNOP= 1.30		
FUEL TANKS (NO.= 1) (ELLIPSOIDAL)		41.39
DIAMETER= 2.665 M		
LENGTH = 1.885 M		
VOLUME = 7.012 M3		
AVG THK = .00064 M		
FS = 1.50, FNOP= 1.30		
PRESSURANT		4.986
PRESSURANT TANKS (NO.= 1)		26.64
DIA= .6100 M		
VOL= .119 M3		
THK= .00515 M		
FS = 1.50, FNOP= 1.10		
OXIDIZER TANK INSULATION		44.45
ENGINES (NO.= 1)		37.65
COMPONENTS AND LINES		363.33
ENG. MOUNTS, SUPPORTS		1260.08
TOTAL WET SYSTEM MASS		23561.6
TOTAL BURNOUT MASS (INCL.NON-USABLE PROP. AND GAS)		2565.9
MASS FRACTION		.882
TOTAL IMPULSE		68665193.8 N-S

PRESSURE SCHEDULE(N/M2) AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =	.2482E+08	INITIAL CHAMBER PRESSURE =	0.
INITIAL OX SYS PRESSURE =	.1517E+06	FINAL OX SYS PRESSURE =	.1517E+06
INITIAL FU SYS PRESSURE =	.1034E+06	FINAL FU SYS PRESSURE =	.1034E+06

9 BURNS, CONSTANT ACCELERATION, T/M=0.01

RP-1/LO2. MAX. PERF., PUMP FED. MR = 3.2

VEHICLE MASS =27215.5 KG DELTA V= 4815.8 M/S AVE. ISP=3285.1 N-S/KG

TOTAL PROPELLANT		21770.00 KG
USABLE FUEL	4959.85	
USABLE OXIDIZER	15871.53	
FUEL TRAPPED	172.27	
OXID TRAPPED	547.14	
FUEL START-S/D LOSSES	6.80	
OXID START-S/D LOSSES	6.80	
OXIDIZER BOILOFF	205.60	
OXIDIZER TANKS (NO.= 1) (ELLIPSOIDAL) DIAMETER= 3.471 M LENGTH = 2.454 M VOLUME = 15.480 M3 AVG THK = .00064 M FS = 1.50, FNOP= 1.30		70.18
FUEL TANKS (NO.= 1) (ELLIPSOIDAL) DIAMETER= 2.625 M LENGTH = 1.856 M VOLUME = 6.696 M3 AVG THK = .00064 M FS = 1.50, FNOP= 1.30		40.13
PRESSURANT		5.036
PRESSURANT TANKS (NO.= 1) DIA= .6121 M VOL= .120 M3 THK= .00516 M FS = 1.50, FNOP= 1.10		26.92
OXIDIZER TANK INSULATION		44.99
ENGINES (NO.= 1)		37.65
COMPONENTS AND LINES		363.33
ENG. MOUNTS,SUPPORTS		1260.08
TOTAL WET SYSTEM MASS		23618.3
TOTAL BURNOUT MASS (INCL.NON-USABLE PROP. AND GAS)		2567.7
MASS FRACTION		.882
TOTAL IMPULSE		68435810.4 N-S

PRESSURE SCHEDULE(N/M2) AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =	.2482E+08	INITIAL CHAMBER PRESSURE =	0.
INITIAL OX SYS PRESSURE =	.1517E+06	FINAL OX SYS PRESSURE =	.1517E+06
INITIAL FU SYS PRESSURE =	.1034E+06	FINAL FU SYS PRESSURE =	.1034E+06

9 BURNS, CONSTANT ACCELERATION, T/M=0.015

RP-1/LO2, MAX. PERF., PUMP FED, MR = 2.8

VEHICLE MASS =27215.5 KG DELTA V= 4480.6 M/S AVE. ISP=3368.4 N-S/KG

TOTAL PROPELLANT		20829.09 KG
USABLE FUEL	5243.03	
USABLE OXIDIZER	14680.48	
FUEL TRAPPED	181.99	
OXID TRAPPED	506.29	
FUEL START-S/D LOSSES	7.26	
OXID START-S/D LOSSES	7.26	
OXIDIZER BOILOFF	202.79	
OXIDIZER TANKS (NO.= 1) (ELLIPSOIDAL)		66.66
DIAMETER= 3.383 M		
LENGTH = 2.392 M		
VOLUME = 14.332 M3		
AVG THK = .00064 M		
FS = 1.50, FNOP= 1.30		
FUEL TANKS (NO.= 1) (ELLIPSOIDAL)		41.65
DIAMETER= 2.674 M		
LENGTH = 1.891 M		
VOLUME = 7.078 M3		
AVG THK = .00064 M		
FS = 1.50, FNOP= 1.30		
PRESSURANT		4.744
PRESSURANT TANKS (NO.= 1)		25.34
DIA= .5998 M		
VOL= .113 M3		
THK= .00506 M		
FS = 1.50, FNOP= 1.10		
OXIDIZER TANK INSULATION		42.73
ENGINES (NO.= 1)		39.46
COMPONENTS AND LINES		363.33
ENG. MOUNTS, SUPPORTS		1250.55
TOTAL WET SYSTEM MASS		22663.6
TOTAL BURNOUT MASS (INCL.NON-USABLE PROP. AND GAS)		2522.7
MASS FRACTION		.879
TOTAL IMPULSE		67113974.8 N-S

PRESSURE SCHEDULE(N/M2) AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =	.2482E+08	INITIAL CHAMBER PRESSURE =	0.
INITIAL OX SYS PRESSURE =	.1517E+06	FINAL OX SYS PRESSURE =	.1517E+06
INITIAL FU SYS PRESSURE =	.1034E+06	FINAL FU SYS PRESSURE =	.1034E+06

9 BURNS, CONSTANT ACCELERATION, T/M=0.015

RP-1/LO2, MAX. PERF., PUMP FED, MR = 3.0

VEHICLE MASS =27215.5 KG DELTA V= 4480.6 M/S AVE. ISP=3348.8 N-S/KG

TOTAL PROPELLANT		20886.83 KG
USABLE FUEL	4994.66	
USABLE OXIDIZER	14983.99	
FUEL TRAPPED	173.50	
OXID TRAPPED	516.65	
FUEL START-S/D LOSSES	7.26	
OXID START-S/D LOSSES	7.26	
OXIDIZER BOILOFF	203.51	
OXIDIZER TANKS (NO.= 1)		67.56
(ELLIPSOIDAL)		
DIAMETER= 3.406 M		
LENGTH = 2.408 M		
VOLUME = 14.624 M3		
AVG THK = .00064 M		
FS = 1.50, FNOP= 1.30		
FUEL TANKS (NO.= 1)		40.32
(ELLIPSOIDAL)		
DIAMETER= 2.631 M		
LENGTH = 1.860 M		
VOLUME = 6.743 M3		
AVG THK = .00064 M		
FS = 1.50, FNOP= 1.30		
PRESSURANT		4.796
PRESSURANT TANKS (NO.= 1)		25.63
DIA= .6021 M		
VOL= .114 M3		
THK= .00508 M		
FS = 1.50, FNOP= 1.10		
OXIDIZER TANK INSULATION		43.31
ENGINES (NO.= 1)		39.46
COMPONENTS AND LINES		363.33
ENG. MOUNTS, SUPPORTS		1250.55
TOTAL WET SYSTEM MASS		22721.8
TOTAL BURNOUT MASS		2525.1
(INCL.NON-USABLE PROP. AND GAS)		
MASS FRACTION		.879
TOTAL IMPULSE		66907913.1 N-S

PRESSURE SCHEDULE(N/M2) AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =	.2482E+08	INITIAL CHAMBER PRESSURE =	0.
INITIAL OX SYS PRESSURE =	.1517E+06	FINAL OX SYS PRESSURE =	.1517E+06
INITIAL FU SYS PRESSURE =	.1034E+06	FINAL FU SYS PRESSURE =	.1034E+06

9 BURNS, CONSTANT ACCELERATION, T/M=0.015

RP-1/LO2, MAX. PERF., PUMP FED, MR = 3.2

VEHICLE MASS =27215.5 KG DELTA V= 4480.6 M/S AVE. ISP=3319.4 N-S/KG

TOTAL PROPELLANT		20973.02 KG
USABLE FUEL	4776.67	
USABLE OXIDIZER	15285.34	
FUEL TRAPPED	165.78	
OXID TRAPPED	526.49	
FUEL START-S/D LOSSES	7.26	
OXID START-S/D LOSSES	7.26	
OXIDIZER BOILOFF	204.22	
OXIDIZER TANKS (NO.= 1) (ELLIPSOIDAL)		68.46
DIAMETER= 3.428 M		
LENGTH = 2.424 M		
VOLUME = . 14.915 M3		
AVG THK = .00064 M		
FS = 1.50, FNOP= 1.30		
FUEL TANKS (NO.= 1) (ELLIPSOIDAL)		39.14
DIAMETER= 2.592 M		
LENGTH = 1.833 M		
VOLUME = 6.449 M3		
AVG THK = .00064 M		
FS = 1.50, FNOP= 1.30		
PRESSURANT		4.852
PRESSURANT TANKS (NO.= 1)		25.94
DIA= .6045 M		
VOL= .116 M3		
THK= .00510 M		
FS = 1.50, FNOP= 1.10		
OXIDIZER TANK INSULATION		43.89
ENGINES (NO.= 1)		39.46
COMPONENTS AND LINES		363.33
ENG. MOUNTS, SUPPORTS		1250.55
TOTAL WET SYSTEM MASS		22808.6
TOTAL BURNOUT MASS (INCL.NON-USABLE PROP. AND GAS)		2527.9
MASS FRACTION		.880
TOTAL IMPULSE		66596829.7 N-S

PRESSURE SCHEDULE(N/M2) AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =	.2482E+08	INITIAL CHAMBER PRESSURE =	0.
INITIAL OX SYS PRESSURE =	.1517E+06	FINAL OX SYS PRESSURE =	.1517E+06
INITIAL FU SYS PRESSURE =	.1034E+06	FINAL FU SYS PRESSURE =	.1034E+06

9 BURNS, CONSTANT ACCELERATION, T/M=0.1

RP-1/LO2, MAX. PERF., PUMP FED, MR = 2.8

VEHICLE MASS =27215.5 KG DELTA V= 4291.6 M/S AVE. ISP=3487.1 N-S/KG

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TOTAL PROPELLANT                               20065.69 KG
  USABLE FUEL                      5046.12
  USABLE OXIDIZER                 14129.14
  FUEL TRAPPED                      173.83
  OXID TRAPPED                      484.28
  FUEL START-S/D LOSSES              15.42
  OXID START-S/D LOSSES              15.42
  OXIDIZER BOILOFF                  201.47

OXIDIZER TANKS (NO.= 1)                           65.01
 (ELLIPSOIDAL)
  DIAMETER=     3.341 M
  LENGTH  =     2.362 M
  VOLUME  =    13.804 M3
  AVG THK =    .00064 M
  FS = 1.50,  FNOP= 1.30

FUEL TANKS (NO.= 1)                               40.64
 (ELLIPSOIDAL)
  DIAMETER=     2.641 M
  LENGTH  =     1.868 M
  VOLUME  =     6.821 M3
  AVG THK =    .00064 M
  FS = 1.50,  FNOP= 1.30

PRESSURANT                                        4.570

PRESSURANT TANKS (NO.= 1)                         24.41
  DIA=     .5924 M
  VOL=      .109 M3
  THK=    .00500 M
  FS = 1.50,  FNOP= 1.10

OXIDIZER TANK INSULATION                          41.68

ENGINES (NO.= 1)                                  97.98

COMPONENTS AND LINES                             363.33
ENG. MOUNTS,SUPPORTS                            1241.94

TOTAL WET SYSTEM MASS                           21945.2
TOTAL BURNOUT MASS                               2537.7
   (INCL.NON-USABLE PROP. AND GAS)

MASS FRACTION                                      .874
TOTAL IMPULSE                               66868804.8 N-S

            PRESSURE SCHEDULE(N/M2  )   AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =   .2482E+08   INITIAL CHAMBER PRESSURE =0.
INITIAL OX SYS PRESSURE   =   .1517E+06   FINAL OX SYS PRESSURE    =  .1517E+06
INITIAL FU SYS PRESSURE   =   .1034E+06   FINAL FU SYS PRESSURE    =  .1034E+06
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9 BURNS, CONSTANT ACCELERATION, T/M=0.1

RP-1/LO2, MAX. PERF., PUMP FED, MR = 3.0

VEHICLE MASS =27215.5 KG DELTA V= 4291.6 M/S AVE. ISP=3469.4 N-S/KG

TOTAL PROPELLANT		20117.09 KG
USABLE FUEL	4806.06	
USABLE OXIDIZER	14418.19	
FUEL TRAPPED	166.01	
OXID TRAPPED	493.82	
FUEL START-S/D LOSSES	15.42	
OXID START-S/D LOSSES	15.42	
OXIDIZER BOILOFF	202.17	
OXIDIZER TANKS (NO.= 1) (ELLIPSOIDAL)		65.89
DIAMETER= 3.363 M		
LENGTH = 2.378 M		
VOLUME = 14.083 M3		
AVG THK = .00064 M		
FS = 1.50, FNOP= 1.30		
FUEL TANKS (NO.= 1) (ELLIPSOIDAL)		39.34
DIAMETER= 2.599 M		
LENGTH = 1.838 M		
VOLUME = 6.498 M3		
AVG THK = .00064 M		
FS = 1.50, FNOP= 1.30		
PRESSURANT		4.619
PRESSURANT TANKS (NO.= 1)		24.68
DIA= .5946 M		
VOL= .110 M3		
THK= .00502 M		
FS = 1.50, FNOP= 1.10		
OXIDIZER TANK INSULATION		42.24
ENGINES (NO.= 1)		97.98
COMPONENTS AND LINES		363.33
ENG. MOUNTS, SUPPORTS		1241.94
TOTAL WET SYSTEM MASS		21997.1
TOTAL BURNOUT MASS (INCL.NON-USABLE PROP. AND GAS)		2539.8
MASS FRACTION		.874
TOTAL IMPULSE		66700289.7 N-S

PRESSURE SCHEDULE(N/M2) AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =	.2482E+08	INITIAL CHAMBER PRESSURE =	0.
INITIAL OX SYS PRESSURE =	.1517E+06	FINAL OX SYS PRESSURE =	.1517E+06
INITIAL FU SYS PRESSURE =	.1034E+06	FINAL FU SYS PRESSURE =	.1034E+06

9 BURNS, CONSTANT ACCELERATION, T/M=0.1

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RP-1/LO2, MAX. PERF., PUMP FED,              MR = 3.2

VEHICLE MASS  =27215.5 KG    DELTA V=  4291.6 M/S   AVE. ISP=3450.8 N-S/KG

TOTAL PROPELLANT                                20170.58 KG
  USABLE FUEL                         4589.58
  USABLE OXIDIZER                    14686.64
  FUEL TRAPPED                         158.32
  OXID TRAPPED                         502.38
  FUEL START-S/D LOSSES                 15.42
  OXID START-S/D LOSSES                 15.42
  OXIDIZER BOILOFF                     202.81

OXIDIZER TANKS (NO.= 1)                            66.69
 (ELLIPSOIDAL)
  DIAMETER=     3.384 M
  LENGTH  =     2.393 M
  VOLUME  =    14.341 M3
  AVG THK =    .00064 M
  FS = 1.50,  FNOP= 1.30

FUEL TANKS (NO.= 1)                                38.15
 (ELLIPSOIDAL)
  DIAMETER=     2.559 M
  LENGTH  =     1.810 M
  VOLUME  =     6.206 M3
  AVG THK =    .00064 M
  FS = 1.50,  FNOP= 1.30

PRESSURANT                                         4.666

PRESSURANT TANKS (NO.= 1)                          24.95
  DIA=     .5967 M
  VOL=      .111 M3
  THK=    .00503 M
  FS = 1.50,  FNOP= 1.10

OXIDIZER TANK INSULATION                           42.75

ENGINES (NO.= 1)                                   97.98

COMPONENTS AND LINES                              363.33
ENG. MOUNTS,SUPPORTS                             1241.94

TOTAL WET SYSTEM MASS                            22051.0
TOTAL BURNOUT MASS                                2541.2
   (INCL.NON-USABLE PROP. AND GAS)

MASS FRACTION                                       .874
TOTAL IMPULSE                               66521431.9 N-S

             PRESSURE SCHEDULE(N/M2  )    AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =    .2482E+08    INITIAL CHAMBER PRESSURE =0.
INITIAL OX SYS PRESSURE   =    .1517E+06    FINAL OX SYS PRESSURE    =  .1517E+06
INITIAL FU SYS PRESSURE   =    .1034E+06    FINAL FU SYS PRESSURE    =  .1034E+06
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9 BURNS, CONSTANT ACCELERATION, T/M=0.01

RP-1/LO2, MIN. LENGTH, PUMP FED, MR = 2.8

VEHICLE MASS =27215.5 KG DELTA V= 4815.8 M/S AVE. ISP=3334.1 N-S/KG

TOTAL PROPELLANT		21652.58 KG
USABLE FUEL	5443.17	
USABLE OXIDIZER	15240.89	
FUEL TRAPPED	193.54	
OXID TRAPPED	537.78	
FUEL START-S/D LOSSES	6.80	
OXID START-S/D LOSSES	6.80	
OXIDIZER BOILOFF	223.59	
OXIDIZER TANKS (NO.= 1) (TOROIDAL)		106.97
INNER DIA= 1.329 M		
OUTER DIA= 4.267 M		
HEIGHT = 1.469 M		
VOLUME = 14.901 M3		
AVG THK = .00064 M		
FS = 1.50, FNOP= 1.50		
FUEL TANKS (NO.= 1) (ELLIPSOIDAL)		42.72
DIAMETER= 2.708 M		
LENGTH = 1.915 M		
VOLUME = 7.353 M3		
AVG THK = .00064 M		
FS = 1.50, FNOP= 1.30		
PRESSURANT		4.928
PRESSURANT TANKS (NO.= 1)		26.32
DIA= .6075 M		
VOL= .117 M3		
THK= .00513 M		
FS = 1.50, FNOP= 1.10		
OXIDIZER TANK INSULATION		59.43
ENGINES (NO.= 1)		37.65
COMPONENTS AND LINES		386.01
ENG. MOUNTS, SUPPORTS		1253.73
TOTAL WET SYSTEM MASS		23570.3
TOTAL BURNOUT MASS (INCL.NON-USABLE PROP. AND GAS)		2649.1
MASS FRACTION		.878
TOTAL IMPULSE		68966026.3 N-S

PRESSURE SCHEDULE(N/M2) AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =	.2482E+08	INITIAL CHAMBER PRESSURE =	0.
INITIAL OX SYS PRESSURE =	.1517E+06	FINAL OX SYS PRESSURE =	.1517E+06
INITIAL FU SYS PRESSURE =	.1034E+06	FINAL FU SYS PRESSURE =	.1034E+06

9 BURNS, CONSTANT ACCELERATION, T/M=0.01

RP-1/LO2, MIN. LENGTH, PUMP FED, MR = 3.0

VEHICLE MASS =27215.5 KG DELTA V= 4815.8 M/S AVE. ISP=3304.7 N-S/KG

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TOTAL PROPELLANT                                21736.42 KG
  USABLE FUEL                       5191.33
  USABLE OXIDIZER                  15574.00
  FUEL TRAPPED                       184.51
  OXID TRAPPED                       548.88
  FUEL START-S/D LOSSES                6.80
  OXID START-S/D LOSSES                6.80
  OXIDIZER BOILOFF                   224.10

OXIDIZER TANKS (NO.= 1)                           107.70
 (TOROIDAL)
  INNER DIA=     1.286 M
  OUTER DIA=     4.267 M
  HEIGHT   =     1.491 M
  VOLUME   =    15.222 M3
  AVG THK  =    .00064 M
  FS = 1.50,  FNOP= 1.50

FUEL TANKS (NO.= 1)                                41.39
 (ELLIPSOIDAL)
  DIAMETER=    2.666 M
  LENGTH  =    1.885 M
  VOLUME  =    7.013 M3
  AVG THK =   .00064 M
  FS = 1.50,  FNOP= 1.30

PRESSURANT                                          4.988

PRESSURANT TANKS (NO.= 1)                          26.65
  DIA=     .6100 M
  VOL=      .119 M3
  THK=    .00515 M
  FS = 1.50,  FNOP= 1.10

OXIDIZER TANK INSULATION                           59.83

ENGINES (NO.= 1)                                   37.65

COMPONENTS AND LINES                              386.01
ENG. MOUNTS,SUPPORTS                             1253.73

TOTAL WET SYSTEM MASS                            23654.4
TOTAL BURNOUT MASS                                2651.3
   (INCL.NON-USABLE PROP. AND GAS)

MASS FRACTION                                       .878
TOTAL IMPULSE                               68626081.7 N-S

            PRESSURE SCHEDULE(N/M2   )  AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =   .2482E+08   INITIAL CHAMBER PRESSURE =O.
INITIAL OX SYS PRESSURE   =   .1517E+06   FINAL OX SYS PRESSURE    =  .1517E+06
INITIAL FU SYS PRESSURE   =   .1034E+06   FINAL FU SYS PRESSURE    =  .1034E+06
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9 BURNS, CONSTANT ACCELERATION, T/M=0.01

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    RP-1/LO2, MIN. LENGTH, PUMP FED,              MR = 3.2

VEHICLE MASS  =27215.5 KG    DELTA V=  4815.8 M/S   AVE. ISP=3285.1 N-S/KG

TOTAL PROPELLANT                          21792.58 KG
  USABLE FUEL                    4957.06
  USABLE OXIDIZER               15862.61
  FUEL TRAPPED                    175.91
  OXID TRAPPED                    558.86
  FUEL START-S/D LOSSES             6.80
  OXID START-S/D LOSSES             6.80
  OXIDIZER BOILOFF                224.52

OXIDIZER TANKS (NO.= 1)                     109.11
 (TOROIDAL)
  INNER DIA=     1.249 M
  OUTER DIA=     4.267 M
  HEIGHT   =     1.509 M
  VOLUME   =    15.501 M3
  AVG THK  =    .00064 M
  FS = 1.50,  FNOP= 1.50

FUEL TANKS (NO.= 1)                          40.14
 (ELLIPSOIDAL)
  DIAMETER=     2.625 M
  LENGTH  =     1.856 M
  VOLUME  =     6.697 M3
  AVG THK =    .00064 M
  FS = 1.50,  FNOP= 1.30

PRESSURANT                                    5.038

PRESSURANT TANKS (NO.= 1)                    26.93
  DIA=     .6122 M
  VOL=      .120 M3
  THK=    .00517 M
  FS = 1.50,  FNOP= 1.10

OXIDIZER TANK INSULATION                     60.17

ENGINES (NO.= 1)                             37.65

COMPONENTS AND LINES                        386.01
ENG. MOUNTS,SUPPORTS                       1253.73

TOTAL WET SYSTEM MASS                      23711.4
TOTAL BURNOUT MASS                          2653.6
   (INCL.NON-USABLE PROP. AND GAS)

MASS FRACTION                                 .878
TOTAL IMPULSE                          68397332.7 N-S

             PRESSURE SCHEDULE(N/M2  )   AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =   .2482E+08    INITIAL CHAMBER PRESSURE =0.
INITIAL OX SYS PRESSURE   =   .1517E+06    FINAL OX SYS PRESSURE    =  .1517E+06
INITIAL FU SYS PRESSURE   =   .1034E+06    FINAL FU SYS PRESSURE    =  .1034E+06
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9 BURNS, CONSTANT ACCELERATION, T/M=0.015

RP-1/LO2, MIN. LENGTH, PUMP FED, MR = 2.8

VEHICLE MASS =27215.5 KG DELTA V= 4480.6 M/S AVE. ISP=3368.4 N-S/KG

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TOTAL PROPELLANT                               20852.59 KG
  USABLE FUEL                      5239.93
  USABLE OXIDIZER                 14671.80
  FUEL TRAPPED                      186.09
  OXID TRAPPED                      517.57
  FUEL START-S/D LOSSES               7.26
  OXID START-S/D LOSSES               7.26
  OXIDIZER BOILOFF                  222.69

OXIDIZER TANKS (NO.= 1)                          105.66
 (TOROIDAL)
  INNER DIA=     1.402 M
  OUTER DIA=     4.267 M
  HEIGHT   =     1.432 M
  VOLUME   =    14.353 M3
  AVG THK  =    .00064 M
  FS = 1.50,  FNOP= 1.50

FUEL TANKS (NO.= 1)                               41.65
 (ELLIPSOIDAL)
  DIAMETER=     2.674 M
  LENGTH  =     1.891 M
  VOLUME  =     7.079 M3
  AVG THK =    .00064 M
  FS = 1.50,  FNOP= 1.30

PRESSURANT                                        4.746

PRESSURANT TANKS (NO.= 1)                         25.35
  DIA=     .5999 M
  VOL=      .113 M3
  THK=    .00506 M
  FS = 1.50,  FNOP= 1.10

OXIDIZER TANK INSULATION                          58.70

ENGINES (NO.= 1)                                  39.46

COMPONENTS AND LINES                             386.01
ENG. MOUNTS,SUPPORTS                            1243.75

TOTAL WET SYSTEM MASS                           22757.9
TOTAL BURNOUT MASS                               2609.0
   (INCL.NON-USABLE PROP. AND GAS)

MASS FRACTION                                      .875
TOTAL IMPULSE                            67074296.7 N-S

            PRESSURE SCHEDULE(N/M2 )  AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =  .2482E+08   INITIAL CHAMBER PRESSURE =0.
INITIAL OX SYS PRESSURE   =  .1517E+06   FINAL OX SYS PRESSURE   =  .1517E+06
INITIAL FU SYS PRESSURE   =  .1034E+06   FINAL FU SYS PRESSURE   =  .1034E+06
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9 BURNS, CONSTANT ACCELERATION, T/M=0.015

RP-1/LO2, MIN. LENGTH, PUMP FED, MR = 3.0

VEHICLE MASS =27215.5 KG DELTA V= 4480.6 M/S AVE. ISP=3348.8 N-S/KG

TOTAL PROPELLANT		20909.75 KG
USABLE FUEL	4991.75	
USABLE OXIDIZER	14975.24	
FUEL TRAPPED	177.15	
OXID TRAPPED	527.92	
FUEL START-S/D LOSSES	7.26	
OXID START-S/D LOSSES	7.26	
OXIDIZER BOILOFF	223.18	
OXIDIZER TANKS (NO.= 1)		106.37
(TOROIDAL)		
INNER DIA= 1.363 M		
OUTER DIA= 4.267 M		
HEIGHT = 1.452 M		
VOLUME = 14.645 M3		
AVG THK = .00064 M		
FS = 1.50, FNOP= 1.50		
FUEL TANKS (NO.= 1)		40.33
(ELLIPSOIDAL)		
DIAMETER= 2.631 M		
LENGTH = 1.861 M		
VOLUME = 6.744 M3		
AVG THK = .00064 M		
FS = 1.50, FNOP= 1.30		
PRESSURANT		4.798
PRESSURANT TANKS (NO.= 1)		25.64
DIA= .6022 M		
VOL= .114 M3		
THK= .00508 M		
FS = 1.50, FNOP= 1.10		
OXIDIZER TANK INSULATION		59.09
ENGINES (NO.= 1)		39.46
COMPONENTS AND LINES		386.01
ENG. MOUNTS, SUPPORTS		1243.75
TOTAL WET SYSTEM MASS		22815.2
TOTAL BURNOUT MASS		2610.5
(INCL.NON-USABLE PROP. AND GAS)		
MASS FRACTION		.875
TOTAL IMPULSE		66868825.9 N-S

PRESSURE SCHEDULE(N/M2) AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =	.2482E+08	INITIAL CHAMBER PRESSURE =	0.
INITIAL OX SYS PRESSURE =	.1517E+06	FINAL OX SYS PRESSURE =	.1517E+06
INITIAL FU SYS PRESSURE =	.1034E+06	FINAL FU SYS PRESSURE =	.1034E+06

9 BURNS, CONSTANT ACCELERATION, T/M=0.015

RP-1/LO2, MIN. LENGTH, PUMP FED, MR = 3.2

VEHICLE MASS =27215.5 KG DELTA V= 4480.6 M/S AVE. ISP=3319.4 N-S/KG

TOTAL PROPELLANT		20995.79 KG
USABLE FUEL	4773.91	
USABLE OXIDIZER	15276.52	
FUEL TRAPPED	169.43	
OXID TRAPPED	537.76	
FUEL START-S/D LOSSES	7.26	
OXID START-S/D LOSSES	7.26	
OXIDIZER BOILOFF	223.65	

OXIDIZER TANKS (NO.= 1) 107.05
(TOROIDAL)
INNER DIA= 1.324 M
OUTER DIA= 4.267 M
HEIGHT = 1.471 M
VOLUME = 14.935 M3
AVG THK = .00064 M
FS = 1.50, FNOP= 1.50

FUEL TANKS (NO.= 1) 39.15
(ELLIPSOIDAL)
DIAMETER= 2.592 M
LENGTH = 1.833 M
VOLUME = 6.450 M3
AVG THK = .00064 M
FS = 1.50, FNOP= 1.30

PRESSURANT 4.854

PRESSURANT TANKS (NO.= 1) 25.95
DIA= .6046 M
VOL= .116 M3
THK= .00510 M
FS = 1.50, FNOP= 1.10

OXIDIZER TANK INSULATION 59.47

ENGINES (NO.= 1) 39.46

COMPONENTS AND LINES 386.01
ENG. MOUNTS, SUPPORTS 1243.75

TOTAL WET SYSTEM MASS 22901.5
TOTAL BURNOUT MASS 2612.9
(INCL.NON-USABLE PROP. AND GAS)

MASS FRACTION .876
TOTAL IMPULSE 66558404.0 N-S

PRESSURE SCHEDULE(N/M2) AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =	.2482E+08	INITIAL CHAMBER PRESSURE =	0.
INITIAL OX SYS PRESSURE =	.1517E+06	FINAL OX SYS PRESSURE =	.1517E+06
INITIAL FU SYS PRESSURE =	.1034E+06	FINAL FU SYS PRESSURE =	.1034E+06

9 BURNS, CONSTANT ACCELERATION, T/M=0.1

RP-1/LO2, MIN. LENGTH, PUMP FED. , MR = 2.8

VEHICLE MASS =27215.5 KG DELTA V= 4291.6 M/S AVE. ISP=3487.1 N-S/KG

TOTAL PROPELLANT		20109.43 KG
USABLE FUEL	5043.07	
USABLE OXIDIZER	14120.61	
FUEL TRAPPED	183.40	
OXID TRAPPED	509.69	
FUEL START-S/D LOSSES	15.42	
OXID START-S/D LOSSES	15.42	
OXIDIZER BOILOFF	221.80	
OXIDIZER TANKS (NO.= 1)		104.38
(TOROIDAL)		
INNER DIA= 1.471 M		
OUTER DIA= 4.267 M		
HEIGHT = 1.398 M		
VOLUME = 13.839 M3		
AVG THK = .00064 M		
FS = 1.50, FNOP= 1.50		
FUEL TANKS (NO.= 1)		40.67
(ELLIPSOIDAL)		
DIAMETER= 2.642 M		
LENGTH = 1.868 M		
VOLUME = 6.830 M3		
AVG THK = .00064 M		
FS = 1.50, FNOP= 1.30		
PRESSURANT		4.572
PRESSURANT TANKS (NO.= 1)		24.42
DIA= .5925 M		
VOL= .109 M3		
THK= .00500 M		
FS = 1.50, FNOP= 1.10		
OXIDIZER TANK INSULATION		57.99
ENGINES (NO.= 1)		97.98
COMPONENTS AND LINES		386.01
ENG. MOUNTS, SUPPORTS		1231.96
TOTAL WET SYSTEM MASS		22057.4
TOTAL BURNOUT MASS		2641.1
(INCL.NON-USABLE PROP. AND GAS)		
MASS FRACTION		.869
TOTAL IMPULSE		66828425.1 N-S

PRESSURE SCHEDULE(N/M2) AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =	.2482E+08	INITIAL CHAMBER PRESSURE =	0.
INITIAL OX SYS PRESSURE =	.1517E+06	FINAL OX SYS PRESSURE =	.1517E+06
INITIAL FU SYS PRESSURE =	.1034E+06	FINAL FU SYS PRESSURE =	.1034E+06

9 BURNS, CONSTANT ACCELERATION, T/M=0.1

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    RP-1/LO2, MIN. LENGTH, PUMP FED,              MR = 3.0

VEHICLE MASS  =27215.5 KG    DELTA V=  4291.6 M/S   AVE. ISP=3469.4 N-S/KG

TOTAL PROPELLANT                              20160.71 KG
  USABLE FUEL                       4803.19
  USABLE OXIDIZER                  14409.57
  FUEL TRAPPED                       174.67
  OXID TRAPPED                       520.14
  FUEL START-S/D LOSSES               15.42
  OXID START-S/D LOSSES               15.42
  OXIDIZER BOILOFF                   222.29

OXIDIZER TANKS (NO.= 1)                         105.09
 (TOROIDAL)
  INNER DIA=     1.434 M
  OUTER DIA=     4.267 M
  HEIGHT   =     1.417 M
  VOLUME   =    14.118 M3
  AVG THK  =    .00064 M
  FS = 1.50,  FNOP= 1.50

FUEL TANKS (NO.= 1)                              39.37
 (ELLIPSOIDAL)
  DIAMETER=     2.600 M
  LENGTH  =     1.838 M
  VOLUME  =     6.506 M3
  AVG THK =    .00064 M
  FS = 1.50,  FNOP= 1.30

PRESSURANT                                       4.622

PRESSURANT TANKS (NO.= 1)                        24.70
  DIA=     .5947 M
  VOL=      .110 M3
  THK=    .00502 M
  FS = 1.50,  FNOP= 1.10

OXIDIZER TANK INSULATION                         58.38

ENGINES (NO.= 1)                                 97.98

COMPONENTS AND LINES                            386.01
ENG. MOUNTS,SUPPORTS                           1231.96

TOTAL WET SYSTEM MASS                          22108.8
TOTAL BURNOUT MASS                              2642.9
   (INCL.NON-USABLE PROP. AND GAS)

MASS FRACTION                                     .869
TOTAL IMPULSE                               66660424.7 N-S

             PRESSURE SCHEDULE(N/M2  )   AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =   .2482E+08   INITIAL CHAMBER PRESSURE =0.
INITIAL OX SYS PRESSURE   =   .1517E+06   FINAL OX SYS PRESSURE    =  .1517E+06
INITIAL FU SYS PRESSURE   =   .1034E+06   FINAL FU SYS PRESSURE    =  .1034E+06
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9 BURNS, CONSTANT ACCELERATION, T/M=0.01

RP-1/LO2, MIN. LENGTH, PUMP FED, MR = 3.2

VEHICLE MASS =27215.5 KG DELTA V= 4291.6 M/S AVE. ISP=3450.8 N-S/KG

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TOTAL PROPELLANT                                  20214.07 KG
  USABLE FUEL                         4586.86
  USABLE OXIDIZER                    14677.95
  FUEL TRAPPED                         166.53
  OXID TRAPPED                         529.16
  FUEL START-S/D LOSSES                 15.42
  OXID START-S/D LOSSES                 15.42
  OXIDIZER BOILOFF                     222.73

OXIDIZER TANKS (NO.= 1)                             105.72
 (TOROIDAL)
  INNER DIA=     1.399 M
  OUTER DIA=     4.267 M
  HEIGHT   =     1.434 M
  VOLUME   =    14.377 M3
  AVG THK  =    .00064 M
  FS = 1.50,   FNOP= 1.50

FUEL TANKS (NO.= 1)                                  38.18
 (ELLIPSOIDAL)
  DIAMETER=     2.560 M
  LENGTH  =     1.810 M
  VOLUME  =     6.213 M3
  AVG THK =    .00064 M
  FS = 1.50,   FNOP= 1.30

PRESSURANT                                           4.668

PRESSURANT TANKS (NO.= 1)                            24.96
  DIA=     .5968 M
  VOL=      .111 M3
  THK=    .00504 M
  FS = 1.50,   FNOP= 1.10

OXIDIZER TANK INSULATION                             58.74

ENGINES (NO.= 1)                                     97.98

COMPONENTS AND LINES                                386.01
ENG. MOUNTS,SUPPORTS                               1231.96

TOTAL WET SYSTEM MASS                              22162.3
TOTAL BURNOUT MASS                                  2643.9
   (INCL.NON-USABLE PROP. AND GAS)

MASS FRACTION                                         .869
TOTAL IMPULSE                                   66482071.3 N-S

             PRESSURE SCHEDULE(N/M2  )   AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =   .2482E+08    INITIAL CHAMBER PRESSURE =0.
INITIAL OX SYS PRESSURE   =   .1517E+06    FINAL OX SYS PRESSURE    =  .1517E+06
INITIAL FU SYS PRESSURE   =   .1034E+06    FINAL FU SYS PRESSURE    =  .1034E+06
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9 BURNS, CONSTANT ACCELERATION, T/M=0.01

LCH4/LO2 MAX PERF PRESS FED MR=3.4

VEHICLE MASS =27215.5 KG , DELTA V= 4815.8 M/S AVE. ISP=3510.6 N-S/KG

TOTAL PROPELLANT		21211.34 KG
USABLE FUEL	4585.51	
USABLE OXIDIZER	15590.73	
FUEL TRAPPED	153.31	
OXID TRAPPED	567.02	
FUEL START-S/D LOSSES	15.42	
OXID START-S/D LOSSES	15.42	
FUEL BOILOFF	80.01	
OXIDIZER BOILOFF	203.91	
OXIDIZER TANKS (NO.= 1)		414.66
(ELLIPSOIDAL)		
DIAMETER= 3.418 M		
LENGTH = 2.417 M		
VOLUME = 14.788 M3		
AVG THK = .00387 M		
FS = 1.50, FNOP= 1.30		
FUEL TANKS (NO.= 1)		362.66
(ELLIPSOIDAL)		
DIAMETER= 3.170 M		
LENGTH = 2.241 M		
VOLUME = 11.792 M3		
AVG THK = .00393 M		
FS = 1.50, FNOP= 1.30		
PRESSURANT		71.067
PRESSURANT TANKS (NO.= 1)		385.06
DIA= 1.4858 M		
VOL= 1.717 M3		
THK= .01254 M		
FS = 1.50, FNOP= 1.10		
FUEL TANK INSULATION		26.27
OXIDIZER TANK INSULATION		43.64
ENGINES (NO.= 1)		34.02
COMPONENTS AND LINES		554.74
ENG. MOUNTS, SUPPORTS		1322.22
TOTAL WET SYSTEM MASS		24425.7
TOTAL BURNOUT MASS		3934.7
(INCL.NON-USABLE PROP. AND GAS)		
MASS FRACTION		.826
TOTAL IMPULSE		70834325.8 N-S

PRESSURE SCHEDULE(N/M2) AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =	.2482E+08	INITIAL CHAMBER PRESSURE =	0.
INITIAL OX SYS PRESSURE =	.1069E+07	FINAL OX SYS PRESSURE =	.1069E+07
INITIAL FU SYS PRESSURE =	.1172E+07	FINAL FU SYS PRESSURE =	.1172E+07

9 BURNS, CONSTANT ACCELERATION, T/M=0.01

LCH4/LO2 MAX PERF PRESS FED MR=3.7

VEHICLE MASS =27215.5 KG DELTA V= 4815.8 M/S AVE. ISP=3461.6 N-S/KG

TOTAL PROPELLANT		21346.55 KG
USABLE FUEL	4320.90	
USABLE OXIDIZER	15987.33	
FUEL TRAPPED	141.61	
OXID TRAPPED	581.99	
FUEL START-S/D LOSSES	15.42	
OXID START-S/D LOSSES	15.42	
FUEL BOILOFF	79.05	
OXIDIZER BOILOFF	204.82	

OXIDIZER TANKS (NO.= 1) 425.10
(ELLIPSOIDAL)
DIAMETER= 3.447 M
LENGTH = ' 2.437 M
VOLUME = 15.161 M3
AVG THK = .00390 M
FS = 1.50, FNOP= 1.30

FUEL TANKS (NO.= 1) 341.86
(ELLIPSOIDAL)
DIAMETER= 3.108 M
LENGTH = 2.198 M
VOLUME = 11.116 M3
AVG THK = .00386 M
FS = 1.50, FNOP= 1.30

PRESSURANT 70.565

PRESSURANT TANKS (NO.= 1) 382.38
DIA= 1.4824 M
VOL= 1.706 M3
THK= .01251 M
FS = 1.50, FNOP= 1.10

FUEL TANK INSULATION	25.25
OXIDIZER TANK INSULATION	44.37
ENGINES (NO.= 1)	34.02
COMPONENTS AND LINES	554.74
ENG. MOUNTS, SUPPORTS	1322.22
TOTAL WET SYSTEM MASS	24547.1
TOTAL BURNOUT MASS (INCL.NON-USABLE PROP. AND GAS)	3924.1
MASS FRACTION	.827
TOTAL IMPULSE	70301918.9 N-S

PRESSURE SCHEDULE(N/M2) AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =	.2482E+08	INITIAL CHAMBER PRESSURE =0.	
INITIAL OX SYS PRESSURE =	.1069E+07	FINAL OX SYS PRESSURE =	.1069E+07
INITIAL FU SYS PRESSURE =	.1172E+07	FINAL FU SYS PRESSURE =	.1172E+07

9 BURNS, CONSTANT ACCELERATION, T/M=0.01

LCH4/LO2 MAX PERF PRESS FED MR=4.0

VEHICLE MASS =27215.5 KG DELTA V= 4815.8 M/S AVE. ISP=3402.8 N-S/KG

TOTAL PROPELLANT		21510.40 KG
USABLE FUEL	4093.61	
USABLE OXIDIZER	16374.44	
FUEL TRAPPED	132.22	
OXID TRAPPED	595.36	
FUEL START-S/D LOSSES	15.42	
OXID START-S/D LOSSES	15.42	
FUEL BOILOFF	78.21	
OXIDIZER BOILOFF	205.70	
OXIDIZER TANKS (NO.= 1) (ELLIPSOIDAL)		435.27
DIAMETER= 3.474 M		
LENGTH = 2.456 M		
VOLUME = 15.523 M3		
AVG THK = .00393 M		
FS = 1.50, FNOP= 1.30		
FUEL TANKS (NO.= 1) (ELLIPSOIDAL)		324.04
DIAMETER= 3.053 M		
LENGTH = 2.159 M		
VOLUME = 10.537 M3		
AVG THK = .00379 M		
FS = 1.50, FNOP= 1.30		
PRESSURANT		70.261
PRESSURANT TANKS (NO.= 1)		380.78
DIA= 1.4803 M		
VOL= 1.698 M3		
THK= .01249 M		
FS = 1.50, FNOP= 1.10		
FUEL TANK INSULATION		24.37
OXIDIZER TANK INSULATION		45.07
ENGINES (NO.= 1)		34.02
COMPONENTS AND LINES		554.74
ENG. MOUNTS,SUPPORTS		1322.22
TOTAL WET SYSTEM MASS		24701.2
TOTAL BURNOUT MASS (INCL.NON-USABLE PROP. AND GAS)		3918.4
MASS FRACTION		.829
TOTAL IMPULSE		69650868.1 N-S

PRESSURE SCHEDULE(N/M2) AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =	.2482E+08	INITIAL CHAMBER PRESSURE =	0.
INITIAL OX SYS PRESSURE =	.1069E+07	FINAL OX SYS PRESSURE =	.1069E+07
INITIAL FU SYS PRESSURE =	.1172E+07	FINAL FU SYS PRESSURE =	.1172E+07

9 BURNS, CONSTANT ACCELERATION, T/M=0.015

LCH4/LO2 MAX PERF PRESS FED MR=3.4

VEHICLE MASS =27215.5 KG DELTA V= 4480.6 M/S AVE. ISP=3520.4 N-S/KG

TOTAL PROPELLANT		20430.01 KG
USABLE FUEL	4423.48	
USABLE OXIDIZER	15039.83	
FUEL TRAPPED	144.07	
OXID TRAPPED	529.43	
FUEL START-S/D LOSSES	7.26	
OXID START-S/D LOSSES	7.26	
FUEL BOILOFF	78.48	
OXIDIZER BOILOFF	200.20	
OXIDIZER TANKS (NO.= 1) (ELLIPSOIDAL)		399.46
DIAMETER= 3.376 M		
LENGTH = 2.387 M		
VOLUME = 14.246 M3		
AVG THK = .00382 M		
FS = 1.50, FNOP= 1.30		
FUEL TANKS (NO.= 1) (ELLIPSOIDAL)		349.08
DIAMETER= 3.130 M		
LENGTH = 2.213 M		
VOLUME = 11.351 M3		
AVG THK = .00388 M		
FS = 1.50, FNOP= 1.30		
PRESSURANT		68.517
PRESSURANT TANKS (NO.= 1)		371.25
DIA= 1.4678 M		
VOL= 1.656 M3		
THK= .01238 M		
FS = 1.50, FNOP= 1.10		
FUEL TANK INSULATION		25.61
OXIDIZER TANK INSULATION		42.56
ENGINES (NO.= 1)		47.63
COMPONENTS AND LINES		554.74
ENG. MOUNTS,SUPPORTS		1307.25
TOTAL WET SYSTEM MASS		23596.1
TOTAL BURNOUT MASS (INCL.NON-USABLE PROP. AND GAS)		3839.6
MASS FRACTION		.825
TOTAL IMPULSE		68522264.7 N-S

PRESSURE SCHEDULE(N/M2) AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =	.2482E+08	INITIAL CHAMBER PRESSURE =	0.
INITIAL OX SYS PRESSURE =	.1069E+07	FINAL OX SYS PRESSURE =	.1069E+07
INITIAL FU SYS PRESSURE =	.1172E+07	FINAL FU SYS PRESSURE =	.1172E+07

9 BURNS, CONSTANT ACCELERATION, T/M=0.015

LCH4/LO2 MAX PERF PRESS FED MR=3.7

VEHICLE MASS =27215.5 KG DELTA V= 4480.6 M/S AVE. ISP=3481.2 N-S/KG

TOTAL PROPELLANT		20540.44 KG
USABLE FUEL	4164.08	
USABLE OXIDIZER	15407.10	
FUEL TRAPPED	133.41	
OXID TRAPPED	542.75	
FUEL START-S/D LOSSES	7.26	
OXID START-S/D LOSSES	7.26	
FUEL BOILOFF	77.53	
OXIDIZER BOILOFF	201.04	
OXIDIZER TANKS (NO.= 1) (ELLIPSOIDAL)		409.12
DIAMETER= 3.403 M		
LENGTH = 2.406 M		
VOLUME = 14.590 M3		
AVG THK = .00385 M		
FS = 1.50, FNOP= 1.30		
FUEL TANKS (NO.= 1) (ELLIPSOIDAL)		328.75
DIAMETER= 3.068 M		
LENGTH = 2.169 M		
VOLUME = 10.690 M3		
AVG THK = .00381 M		
FS = 1.50, FNOP= 1.30		
PRESSURANT		67.965
PRESSURANT TANKS (NO.= 1)		368.31
DIA= 1.4639 M		
VOL= 1.643 M3		
THK= .01235 M		
FS = 1.50, FNOP= 1.10		
FUEL TANK INSULATION		24.60
OXIDIZER TANK INSULATION		43.25
ENGINES (NO.= 1)		47.63
COMPONENTS AND LINES		554.74
ENG. MOUNTS,SUPPORTS		1307.25
TOTAL WET SYSTEM MASS		23692.1
TOTAL BURNOUT MASS (INCL.NON-USABLE PROP. AND GAS)		3827.8
MASS FRACTION		.826
TOTAL IMPULSE		68134308.9 N-S

PRESSURE SCHEDULE(N/M2) AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =	.2482E+08	INITIAL CHAMBER PRESSURE =	0.
INITIAL OX SYS PRESSURE =	.1069E+07	FINAL OX SYS PRESSURE =	.1069E+07
INITIAL FU SYS PRESSURE =	.1172E+07	FINAL FU SYS PRESSURE =	.1172E+07

9 BURNS, CONSTANT ACCELERATION, T/M=0.015

LCH4/LO2 MAX PERF PRESS FED MR=4.0

VEHICLE MASS =27215.5 KG DELTA V= 4480.6 M/S AVE. ISP=3422.4 N-S/KG

TOTAL PROPELLANT		20707.88 KG
USABLE FUEL	3946.90	
USABLE OXIDIZER	15787.59	
FUEL TRAPPED	124.74	
OXID TRAPPED	555.50	
FUEL START-S/D LOSSES	7.26	
OXID START-S/D LOSSES	7.26	
FUEL BOILOFF	76.73	
OXIDIZER BOILOFF	201.91	
OXIDIZER TANKS (NO.= 1) (ELLIPSOIDAL)		419.09
DIAMETER= 3.430 M		
LENGTH = 2.426 M		
VOLUME = 14.946 M3		
AVG THK = .00388 M		
FS = 1.50, FNOP= 1.30		
FUEL TANKS (NO.= 1) (ELLIPSOIDAL)		311.75
DIAMETER= 3.014 M		
LENGTH = 2.131 M		
VOLUME = 10.137 M3		
AVG THK = .00374 M		
FS = 1.50, FNOP= 1.30		
PRESSURANT		67.704
PRESSURANT TANKS (NO.= 1)		366.93
DIA= 1.4621 M		
VOL= 1.637 M3		
THK= .01234 M		
FS = 1.50, FNOP= 1.10		
FUEL TANK INSULATION		23.75
OXIDIZER TANK INSULATION		43.95
ENGINES (NO.= 1)		47.63
COMPONENTS AND LINES		554.74
ENG. MOUNTS, SUPPORTS		1307.25
TOTAL WET SYSTEM MASS		23850.7
TOTAL BURNOUT MASS (INCL.NON-USABLE PROP AND GAS)		3823.0
MASS FRACTION		.827
TOTAL IMPULSE		67541666.5 N-S

PRESSURE SCHEDULE(N/M2) AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =	.2482E+08	INITIAL CHAMBER PRESSURE =	0.
INITIAL OX SYS PRESSURE =	.1069E+07	FINAL OX SYS PRESSURE =	.1069E+07
INITIAL FU SYS PRESSURE =	.1172E+07	FINAL FU SYS PRESSURE =	.1172E+07

9 BURNS, CONSTANT ACCELERATION, T/M=0.1

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   LCH4/LO2   MAX PERF   PRESS FED                  MR=3.4

VEHICLE MASS   =27215.5 KG     DELTA V=  4291.6 M/S    AVE. ISP=3559.7 N-S/KG

TOTAL PROPELLANT                                19878.14 KG
  USABLE FUEL                        4304.20
  USABLE OXIDIZER                   14634.29
  FUEL TRAPPED                        139.63
  OXID TRAPPED                        512.39
  FUEL START-S/D LOSSES                 6.80
  OXID START-S/D LOSSES                 6.80
  FUEL BOILOFF                         77.14
  OXIDIZER BOILOFF                    196.87

OXIDIZER TANKS (NO.= 1)                          388.66
 (ELLIPSOIDAL)
  DIAMETER=     3.345 M
  LENGTH  =     2.365 M
  VOLUME  =    13.861 M3
  AVG THK =    .00379 M
  FS = 1.50,   FNOP= 1.30

FUEL TANKS (NO.= 1)                              339.67
 (ELLIPSOIDAL)
  DIAMETER=     3.101 M
  LENGTH  =     2.193 M
  VOLUME  =    11.045 M3
  AVG THK =    .00385 M
  FS = 1.50,   FNOP= 1.30

PRESSURANT                                       66.675

PRESSURANT TANKS (NO.= 1)                        361.27
  DIA=    1.4545 M
  VOL=      1.611 M3
  THK=    .01227 M
  FS = 1.50,  FNOP= 1.10

FUEL TANK INSULATION                              25.15
OXIDIZER TANK INSULATION                          41.79

ENGINES (NO.= 1)                                 222.26

COMPONENTS AND LINES                             554.74
ENG. MOUNTS,SUPPORTS                            1302.26

TOTAL WET SYSTEM MASS                           23180.6
TOTAL BURNOUT MASS                               3954.5
   (INCL.NON-USABLE PROP. AND GAS)

MASS FRACTION                                      .817
TOTAL IMPULSE                               67417498.4 N-S

            PRESSURE SCHEDULE(N/M2  )    AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =   .2482E+08    INITIAL CHAMBER PRESSURE =0.
INITIAL OX SYS PRESSURE   =   .1069E+07    FINAL OX SYS PRESSURE    =  .1069E+07
INITIAL FU SYS PRESSURE   =   .1172E+07    FINAL FU SYS PRESSURE    =  .1172E+07
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9 BURNS, CONSTANT ACCELERATION, T/M=0.1

LCH4/LO2 MAX PERF PRESS FED MR=3.7

VEHICLE MASS =27215.5 KG DELTA V= 4291.6 M/S AVE. ISP=3530.2 N-S/KG

TOTAL PROPELLANT		19961.97 KG
USABLE FUEL	4046.43	
USABLE OXIDIZER	14971.80	
FUEL TRAPPED	129.01	
OXID TRAPPED	524.98	
FUEL START-S/D LOSSES	6.80	
OXID START-S/D LOSSES	6.80	
FUEL BOILOFF	76.20	
OXIDIZER BOILOFF	199.93	
OXIDIZER TANKS (NO.= 1) (ELLIPSOIDAL)		397.61
DIAMETER= 3.371 M		
LENGTH = 2.383 M		
VOLUME = 14.180 M3		
AVG THK = .00381 M		
FS = 1.50, FNOP= 1.30		
FUEL TANKS (NO.= 1) (ELLIPSOIDAL)		319.46
DIAMETER= 3.039 M		
LENGTH = 2.149 M		
VOLUME = 10.388 M3		
AVG THK = .00377 M		
FS = 1.50, FNOP= 1.30		
PRESSURANT		70.488
PRESSURANT TANKS (NO.= 1)		382.46
DIA= 1.4824 M		
VOL= 1.706 M3		
THK= .01251 M		
FS = 1.50, FNOP= 1.10		
FUEL TANK INSULATION		24.14
OXIDIZER TANK INSULATION		42.43
ENGINES (NO.= 1)		222.26
COMPONENTS AND LINES		554.74
ENG. MOUNTS,SUPPORTS		1302.26
TOTAL WET SYSTEM MASS		23277.8
TOTAL BURNOUT MASS (INCL.NON-USABLE PROP. AND GAS)		3969.8
MASS FRACTION		.817
TOTAL IMPULSE		67141817.1 N-S

PRESSURE SCHEDULE(N/M2) AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =	.2482E+08	INITIAL CHAMBER PRESSURE =	0.
INITIAL OX SYS PRESSURE =	.1069E+07	FINAL OX SYS PRESSURE =	.1069E+07
INITIAL FU SYS PRESSURE =	.1172E+07	FINAL FU SYS PRESSURE =	.1172E+07

9 BURNS, CONSTANT ACCELERATION, T/M=0.1

LCH4/LO2 MAX PERF PRESS FED MR=4.0

VEHICLE MASS =27215.5 KG DELTA V= 4291.6 M/S AVE. ISP=3461.6 N-S/KG

TOTAL PROPELLANT		20164.09 KG
USABLE FUEL	3842.08	
USABLE OXIDIZER	15368.31	
FUEL TRAPPED	127.95	
OXID TRAPPED	538.12	
FUEL START-S/D LOSSES	6.80	
OXID START-S/D LOSSES	6.80	
FUEL BOILOFF	75.46	
OXIDIZER BOILOFF	198.56	
OXIDIZER TANKS (NO.= 1) (ELLIPSOIDAL)		407.94
DIAMETER= 3.400 M		
LENGTH = 2.404 M		
VOLUME = 14.549 M3		
AVG THK = .00385 M		
FS = 1.50, FNOP= 1.30		
FUEL TANKS (NO.= 1) (ELLIPSOIDAL)		304.00
DIAMETER= 2.989 M		
LENGTH = 2.113 M		
VOLUME = 9.885 M3		
AVG THK = .00371 M		
FS = 1.50, FNOP= 1.30		
PRESSURANT		65.913
PRESSURANT TANKS (NO.= 1)		357.22
DIA= 1.4491 M		
VOL= 1.593 M3		
THK= .01223 M		
FS = 1.50, FNOP= 1.10		
FUEL TANK INSULATION		23.35
OXIDIZER TANK INSULATION		43.16
ENGINES (NO.= 1)		222.26
COMPONENTS AND LINES		554.74
ENG. MOUNTS,SUPPORTS		1302.26
TOTAL WET SYSTEM MASS		23444.9
TOTAL BURNOUT MASS (INCL.NON-USABLE PROP. AND GAS)		3946.9
MASS FRACTION		.819
TOTAL IMPULSE		66501476.9 N-S

PRESSURE SCHEDULE(N/M2) AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =	.2482E+08	INITIAL CHAMBER PRESSURE =	0.
INITIAL OX SYS PRESSURE =	.1069E+07	FINAL OX SYS PRESSURE =	.1069E+07
INITIAL FU SYS PRESSURE =	.1172E+07	FINAL FU SYS PRESSURE =	.1172E+07

9 BURNS, CONSTANT ACCELERATION, T/M=0.01

LCH4/LO2 MIN LENGTH PRESS FED MR=3.4

VEHICLE MASS =27215.5 KG DELTA V= 4815.8 M/S AVE. ISP=3510.6 N-S/KG

TOTAL PROPELLANT		21255.04 KG
USABLE FUEL	4582.84	
USABLE OXIDIZER	15581.65	
FUEL TRAPPED	159.24	
OXID TRAPPED	596.98	
FUEL START-S/D LOSSES	15.42	
OXID START-S/D LOSSES	15.42	
FUEL BOILOFF	80.02	
OXIDIZER BOILOFF	223.47	
OXIDIZER TANKS (NO.= 1) (TOROIDAL)		548.21
INNER DIA= 1.339 M		
OUTER DIA= 4.267 M		
HEIGHT = 1.464 M		
VOLUME = 14.825 M3		
AVG THK = .00326 M		
FS = 1.50, FNOP= 1.50		
FUEL TANKS (NO.= 1) (ELLIPSOIDAL)		362.90
DIAMETER= 3.171 M		
LENGTH = 2.242 M		
VOLUME = 11.800 M3		
AVG THK = .00394 M		
FS = 1.50, FNOP= 1.30		
PRESSURANT		71.070
PRESSURANT TANKS (NO.= 1)		385.06
DIA= 1.4858 M		
VOL= 1.717 M3		
THK= .01254 M		
FS = 1.50, FNOP= 1.10		
FUEL TANK INSULATION		26.28
OXIDIZER TANK INSULATION		59.33
ENGINES (NO.= 1)		34.02
COMPONENTS AND LINES		589.67
ENG. MOUNTS,SUPPORTS		1305.44
TOTAL WET SYSTEM MASS		24637.0
TOTAL BURNOUT MASS (INCL.NON-USABLE PROP. AND GAS)		4138.2
MASS FRACTION		.818
TOTAL IMPULSE		70793072.3 N-S

PRESSURE SCHEDULE(N/M2) AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =	.2482E+08	INITIAL CHAMBER PRESSURE =	0.
INITIAL OX SYS PRESSURE =	.1069E+07	FINAL OX SYS PRESSURE =	.1069E+07
INITIAL FU SYS PRESSURE =	.1172E+07	FINAL FU SYS PRESSURE =	.1172E+07

9 BURNS, CONSTANT ACCELERATION, T/M=0.01

LCH4/LO2   MIN LENGTH   PRESS FED   MR=3.7

VEHICLE MASS =27215.5 KG   DELTA V= 4815.8 M/S   AVE. ISP=3461.6 N-S/KG

TOTAL PROPELLANT		21390.04 KG
USABLE FUEL	4318.42	
USABLE OXIDIZER	15978.17	
FUEL TRAPPED	146.62	
OXID TRAPPED	612.86	
FUEL START-S/D LOSSES	15.42	
OXID START-S/D LOSSES	15.42	
FUEL BOILOFF	79.06	
OXIDIZER BOILOFF	224.06	
OXIDIZER TANKS (NO.= 1) (TOROIDAL)		568.60
INNER DIA= 1.289 M		
OUTER DIA= 4.267 M		
HEIGHT = 1.489 M		
VOLUME = 15.197 M3		
AVG THK = .00335 M		
FS = 1.50, FNOP= 1.50		
FUEL TANKS (NO.= 1) (ELLIPSOIDAL)		342.05
DIAMETER= 3.109 M		
LENGTH = 2.198 M		
VOLUME = 11.122 M3		
AVG THK = .00386 M		
FS = 1.50, FNOP= 1.30		
PRESSURANT		70.568
PRESSURANT TANKS (NO.= 1)		382.39
DIA= 1.4824 M		
VOL= 1.706 M3		
THK= .01251 M		
FS = 1.50, FNOP= 1.10		
FUEL TANK INSULATION		25.26
OXIDIZER TANK INSULATION		59.80
ENGINES (NO.= 1)		34.02
COMPONENTS AND LINES		589.67
ENG. MOUNTS, SUPPORTS		1305.44
TOTAL WET SYSTEM MASS		24767.8
TOTAL BURNOUT MASS (INCL.NON-USABLE PROP. AND GAS)		4137.3
MASS FRACTION		.819
TOTAL IMPULSE		70261647.7 N-S

PRESSURE SCHEDULE(N/M2) AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =	.2482E+08	INITIAL CHAMBER PRESSURE =	0.
INITIAL OX SYS PRESSURE =	.1069E+07	FINAL OX SYS PRESSURE =	.1069E+07
INITIAL FU SYS PRESSURE =	.1172E+07	FINAL FU SYS PRESSURE =	.1172E+07

9 BURNS, CONSTANT ACCELERATION, T/M=0.01

LCH4/LO2 MIN LENGTH PRESS FED MR=4.0

VEHICLE MASS =27215.5 KG DELTA V= 4815.8 M/S AVE. ISP=3402.8 N-S/KG

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TOTAL PROPELLANT                               21553.67 KG
  USABLE FUEL                      4091.31
  USABLE OXIDIZER                 16365.22
  FUEL TRAPPED                      136.33
  OXID TRAPPED                      627.13
  FUEL START-S/D LOSSES              15.42
  OXID START-S/D LOSSES              15.42
  FUEL BOILOFF                       78.22
  OXIDIZER BOILOFF                  224.61

OXIDIZER TANKS (NO.= 1)                          589.34
 (TOROIDAL)
  INNER DIA=     1.241 M
  OUTER DIA=     4.267 M
  HEIGHT   =     1.513 M
  VOLUME   =    15.560 M3
  AVG THK  =    .00345 M
  FS = 1.50,  FNOP= 1.50

FUEL TANKS (NO.= 1)                              324.18
 (ELLIPSOIDAL)
  DIAMETER=    3.054 M
  LENGTH  =    2.159 M
  VOLUME  =   10.541 M3
  AVG THK =   .00379 M
  FS = 1.50,  FNOP= 1.30

PRESSURANT                                       70.264

PRESSURANT TANKS (NO.= 1)                        380.79
  DIA=    1.4803 M
  VOL=     1.698 M3
  THK=    .01249 M
  FS = 1.50,  FNOP= 1.10

FUEL TANK INSULATION                              24.37
OXIDIZER TANK INSULATION                          60.25

ENGINES (NO.= 1)                                  34.02

COMPONENTS AND LINES                             589.67
ENG. MOUNTS,SUPPORTS                            1305.44

TOTAL WET SYSTEM MASS                           24932.0
TOTAL BURNOUT MASS                               4141.8
   (INCL.NON-USABLE PROP. AND GAS)

MASS FRACTION                                      .820
TOTAL IMPULSE                               69611646.4 N-S

             PRESSURE SCHEDULE(N/M2  )   AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =   .2482E+08   INITIAL CHAMBER PRESSURE =0.
INITIAL OX SYS PRESSURE   =   .1069E+07   FINAL OX SYS PRESSURE    =  .1069E+07
INITIAL FU SYS PRESSURE   =   .1172E+07   FINAL FU SYS PRESSURE    =  .1172E+07
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9 BURNS, CONSTANT ACCELERATION, T/M=0.015

LCH4/LO2 MIN LENGTH PRESS FED MR=3.4

VEHICLE MASS =27215.5 KG DELTA V= 4480.6 M/S AVE. ISP=3520.4 N-S/KG

TOTAL PROPELLANT		20491.98 KG
USABLE FUEL	4420.84	
USABLE OXIDIZER	15030.86	
FUEL TRAPPED	153.19	
OXID TRAPPED	573.98	
FUEL START-S/D LOSSES	7.26	
OXID START-S/D LOSSES	7.26	
FUEL BOILOFF	78.50	
OXIDIZER BOILOFF	220.09	
OXIDIZER TANKS (NO.= 1) (TOROIDAL)		520.70
INNER DIA= 1.410 M		
OUTER DIA= 4.267 M		
HEIGHT = 1.429 M		
VOLUME = 14.296 M3		
AVG THK = .00313 M		
FS = 1.50, FNOP= 1.50		
FUEL TANKS (NO.= 1) (ELLIPSOIDAL)		349.57
DIAMETER= 3.131 M		
LENGTH = 2.214 M		
VOLUME = 11.367 M3		
AVG THK = .00389 M		
FS = 1.50, FNOP= 1.30		
PRESSURANT		68.522
PRESSURANT TANKS (NO.= 1)		371.26
DIA= 1.4678 M		
VOL= 1.656 M3		
THK= .01238 M		
FS = 1.50, FNOP= 1.10		
FUEL TANK INSULATION		25.63
OXIDIZER TANK INSULATION		58.63
ENGINES (NO.= 1)		47.63
COMPONENTS AND LINES		589.67
ENG. MOUNTS, SUPPORTS		1293.65
TOTAL WET SYSTEM MASS		23817.2
TOTAL BURNOUT MASS (INCL.NON-USABLE PROP. AND GAS)		4052.4
MASS FRACTION		.817
TOTAL IMPULSE		68481392.2 N-S

PRESSURE SCHEDULE(N/M2) AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =	.2482E+08	INITIAL CHAMBER PRESSURE =	0.
INITIAL OX SYS PRESSURE =	.1069E+07	FINAL OX SYS PRESSURE =	.1069E+07
INITIAL FU SYS PRESSURE =	.1172E+07	FINAL FU SYS PRESSURE =	.1172E+07

9 BURNS, CONSTANT ACCELERATION, T/M=0.015

LCH4/LO2 MIN LENGTH PRESS FED MR=3.7

VEHICLE MASS =27215.5 KG DELTA V= 4480.6 M/S AVE. ISP=3481.2 N-S/KG

TOTAL PROPELLANT		20602.23 KG
USABLE FUEL	4161.63	
USABLE OXIDIZER	15398.04	
FUEL TRAPPED	141.16	
OXID TRAPPED	588.66	
FUEL START-S/D LOSSES	7.26	
OXID START-S/D LOSSES	7.26	
FUEL BOILOFF	77.55	
OXIDIZER BOILOFF	220.66	
OXIDIZER TANKS (NO.= 1)		538.50
(TOROIDAL)		
INNER DIA= 1.364 M		
OUTER DIA= 4.267 M		
HEIGHT = 1.452 M		
VOLUME = 14.641 M3		
AVG THK = .00322 M		
FS = 1.50, FNOP= 1.50		
FUEL TANKS (NO.= 1)		329.15
(ELLIPSOIDAL)		
DIAMETER= 3.069 M		
LENGTH = 2.170 M		
VOLUME = 10.703 M3		
AVG THK = .00381 M		
FS = 1.50, FNOP= 1.30		
PRESSURANT		67.971
PRESSURANT TANKS (NO.= 1)		368.32
DIA= 1.4639 M		
VOL= 1.643 M3		
THK= .01235 M		
FS = 1.50, FNOP= 1.10		
FUEL TANK INSULATION		24.62
OXIDIZER TANK INSULATION		59.09
ENGINES (NO.= 1)		47.63
COMPONENTS AND LINES		589.67
ENG. MOUNTS, SUPPORTS		1293.65
TOTAL WET SYSTEM MASS		23920.8
TOTAL BURNOUT MASS		4048.4
(INCL.NON-USABLE PROP. AND GAS)		
MASS FRACTION		.818
TOTAL IMPULSE		68094234.1 N-S

PRESSURE SCHEDULE(N/M2) AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =	.2482E+08	INITIAL CHAMBER PRESSURE =	0.
INITIAL OX SYS PRESSURE =	.1069E+07	FINAL OX SYS PRESSURE =	.1069E+07
INITIAL FU SYS PRESSURE =	.1172E+07	FINAL FU SYS PRESSURE =	.1172E+07

9 BURNS, CONSTANT ACCELERATION, T/M=0.015

LCH4/LO2 MIN LENGTH PRESS FED MR=4.0

VEHICLE MASS =27215.5 KG DELTA V= 4480.6 M/S AVE. ISP=3422.4 N-S/KG

TOTAL PROPELLANT		20768.99 KG
USABLE FUEL	3944.61	
USABLE OXIDIZER	15778.45	
FUEL TRAPPED	131.12	
OXID TRAPPED	602.32	
FUEL START-S/D LOSSES	7.26	
OXID START-S/D LOSSES	7.26	
FUEL BOILOFF	76.74	
OXIDIZER BOILOFF	221.23	
OXIDIZER TANKS (NO.= 1) (TOROIDAL)		557.57
INNER DIA= 1.316 M		
OUTER DIA= 4.267 M		
HEIGHT = 1.476 M		
VOLUME = 14.998 M3		
AVG THK = .00330 M		
FS = 1.50, FNOP= 1.50		
FUEL TANKS (NO.= 1) (ELLIPSOIDAL)		312.06
DIAMETER= 3.015 M		
LENGTH = 2.132 M		
VOLUME = 10.147 M3		
AVG THK = .00374 M		
FS = 1.50, FNOP= 1.30		
PRESSURANT		67.710
PRESSURANT TANKS (NO.= 1)		366.95
DIA= 1.4621 M		
VOL= 1.637 M3		
THK= .01234 M		
FS = 1.50, FNOP= 1.10		
FUEL TANK INSULATION		23.76
OXIDIZER TANK INSULATION		59.55
ENGINES (NO.= 1)		47.63
COMPONENTS AND LINES		589.67
ENG. MOUNTS, SUPPORTS		1293.65
TOTAL WET SYSTEM MASS		24087.5
TOTAL BURNOUT MASS (INCL.NON-USABLE PROP. AND GAS)		4052.0
MASS FRACTION		.819
TOTAL IMPULSE		67502547.5 N-S

PRESSURE SCHEDULE(N/M2) AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =	.2482E+08	INITIAL CHAMBER PRESSURE =	0.
INITIAL OX SYS PRESSURE =	.1069E+07	FINAL OX SYS PRESSURE =	.1069E+07
INITIAL FU SYS PRESSURE =	.1172E+07	FINAL FU SYS PRESSURE =	.1172E+07

9 BURNS, CONSTANT ACCELERATION, T/M=0.1

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   LCH4/LO2  MIN LENGTH  PRESS FED            MR=3.4

VEHICLE MASS  =27215.5 KG    DELTA V=  4291.6 M/S   AVE. ISP=3559.7 N-S/KG

TOTAL PROPELLANT                          19937.23 KG
  USABLE FUEL                     4301.60
  USABLE OXIDIZER                14625.44
  FUEL TRAPPED                     148.29
  OXID TRAPPED                     554.21
  FUEL START-S/D LOSSES              6.80
  OXID START-S/D LOSSES              6.80
  FUEL BOILOFF                      77.16
  OXIDIZER BOILOFF                 216.93

OXIDIZER TANKS (NO.= 1)                     501.46
 (TOROIDAL)
  INNER DIA=     1.461 M
  OUTER DIA=     4.267 M
  HEIGHT   =     1.403 M
  VOLUME   =    13.909 M3
  AVG THK  =    .00305 M
  FS = 1.50,  FNOP= 1.50

FUEL TANKS (NO.= 1)                         340.12
 (ELLIPSOIDAL)
  DIAMETER=    3.103 M
  LENGTH  =    2.194 M
  VOLUME  =   11.060 M3
  AVG THK =   .00385 M
  FS = 1.50,  FNOP= 1.30

PRESSURANT                                  66.681

PRESSURANT TANKS (NO.= 1)                   361.29
  DIA=   1.4546 M
  VOL=    1.611 M3
  THK=   .01227 M
  FS = 1.50,  FNOP= 1.10

FUEL TANK INSULATION                         25.17
OXIDIZER TANK INSULATION                     58.09

ENGINES (NO.= 1)                            222.26

COMPONENTS AND LINES                        589.67
ENG. MOUNTS,SUPPORTS                       1283.67

TOTAL WET SYSTEM MASS                      23385.6
TOTAL BURNOUT MASS                          4150.9
   (INCL.NON-USABLE PROP. AND GAS)

MASS FRACTION                                 .809
TOTAL IMPULSE                          67376704.6 N-S

             PRESSURE SCHEDULE(N/M2  )   AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =   .2482E+08    INITIAL CHAMBER PRESSURE =0.
INITIAL OX SYS PRESSURE   =   .1069E+07    FINAL OX SYS PRESSURE    =  .1069E+07
INITIAL FU SYS PRESSURE   =   .1172E+07    FINAL FU SYS PRESSURE    =  .1172E+07
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9 BURNS, CONSTANT ACCELERATION, T/M=0.1

LCH4/LO2 MIN LENGTH PRESS FED MR=3.7

VEHICLE MASS =27215.5 KG DELTA V= 4291.6 M/S AVE. ISP=3530.2 N-S/KG

TOTAL PROPELLANT		20019.95 KG
USABLE FUEL	4044.29	
USABLE OXIDIZER	14963.88	
FUEL TRAPPED	136.31	
OXID TRAPPED	568.18	
FUEL START-S/D LOSSES	6.80	
OXID START-S/D LOSSES	6.80	
FUEL BOILOFF	76.22	
OXIDIZER BOILOFF	217.47	
OXIDIZER TANKS (NO.= 1)		517.25
(TOROIDAL)		
INNER DIA= 1.419 M		
OUTER DIA= 4.267 M		
HEIGHT = 1.424 M		
VOLUME = 14.228 M3		
AVG THK = .00312 M		
FS = 1.50, FNOP= 1.50		
FUEL TANKS (NO.= 1)		319.85
(ELLIPSOIDAL)		
DIAMETER= 3.040 M		
LENGTH = 2.150 M		
VOLUME = 10.400 M3		
AVG THK = .00377 M		
FS = 1.50, FNOP= 1.30		
PRESSURANT		66.063
PRESSURANT TANKS (NO.= 1)		357.98
DIA= 1.4501 M		
VOL= 1.597 M3		
THK= .01224 M		
FS = 1.50, FNOP= 1.10		
FUEL TANK INSULATION		24.16
OXIDIZER TANK INSULATION		58.53
ENGINES (NO.= 1)		222.26
COMPONENTS AND LINES		589.67
ENG. MOUNTS, SUPPORTS		1283.67
TOTAL WET SYSTEM MASS		23459.4
TOTAL BURNOUT MASS		4143.9
(INCL.NON-USABLE PROP. AND GAS)		
MASS FRACTION		.810
TOTAL IMPULSE		67106288.0 N-S

PRESSURE SCHEDULE(N/M2) AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =	.2482E+08	INITIAL CHAMBER PRESSURE =0.	
INITIAL OX SYS PRESSURE =	.1069E+07	FINAL OX SYS PRESSURE =	.1069E+07
INITIAL FU SYS PRESSURE =	.1172E+07	FINAL FU SYS PRESSURE =	.1172E+07

9 BURNS, CONSTANT ACCELERATION, T/M=0.01

```
   LCH4/LO2  MIN LENGTH  PRESS FED            MR=4.0

VEHICLE MASS  =27215.5 KG    DELTA V=  4291.6 M/S   AVE. ISP=3461.6 N-S/KG

TOTAL PROPELLANT                          20213.66 KG
  USABLE FUEL                  3839.82
  USABLE OXIDIZER             15359.27
  FUEL TRAPPED                  127.04
  OXID TRAPPED                  580.38
  FUEL START-S/D LOSSES           6.80
  OXID START-S/D LOSSES           6.80
  FUEL BOILOFF                   75.45
  OXIDIZER BOILOFF              218.08

OXIDIZER TANKS (NO.= 1)                     536.13
 (TOROIDAL)
  INNER DIA=     1.370 M
  OUTER DIA=     4.267 M
  HEIGHT   =     1.449 M
  VOLUME   =    14.596 M3
  AVG THK  =    .00320 M
  FS = 1.50,  FNOP= 1.50

FUEL TANKS (NO.= 1)                         303.76
 (ELLIPSOIDAL)
  DIAMETER=    2.988 M
  LENGTH  =    2.113 M
  VOLUME  =    9.877 M3
  AVG THK =   .00371 M
  FS = 1.50,  FNOP= 1.30

PRESSURANT                                  65.918

PRESSURANT TANKS (NO.= 1)                   357.24
  DIA=   1.4491 M
  VOL=     1.593 M3
  THK=   .01223 M
  FS = 1.50,  FNOP= 1.10

FUEL TANK INSULATION                         23.34
OXIDIZER TANK INSULATION                     59.03

ENGINES (NO.= 1)                            222.26

COMPONENTS AND LINES                        589.67
ENG. MOUNTS,SUPPORTS                       1283.67

TOTAL WET SYSTEM MASS                      23654.7
TOTAL BURNOUT MASS                          4148.4
   (INCL.NON-USABLE PROP. AND GAS)

MASS FRACTION                                 .812
TOTAL IMPULSE                           66462367.3 N-S

             PRESSURE SCHEDULE(N/M2  )   AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =   .2482E+08    INITIAL CHAMBER PRESSURE =0.
INITIAL OX SYS PRESSURE   =   .1069E+07    FINAL OX SYS PRESSURE    =  .1069E+07
INITIAL FU SYS PRESSURE   =   .1172E+07    FINAL FU SYS PRESSURE    =  .1172E+07
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9 BURNS, CONSTANT ACCELERATION, T/M=0.01

```
    LCH4/LO2  MAX PERF  PUMP FED              MR=3.4

VEHICLE MASS  =27215.5 KG ,  DELTA V=  4815.8 M/S   AVE. ISP=3549.8 N-S/KG

TOTAL PROPELLANT                              21103.85 KG
  USABLE FUEL                        4561.74
  USABLE OXIDIZER                   15509.92
  FUEL TRAPPED                        152.70
  OXID TRAPPED                        564.99
  FUEL START-S/D LOSSES                15.42
  OXID START-S/D LOSSES                15.42
  FUEL BOILOFF                         79.93
  OXIDIZER BOILOFF                    203.73

OXIDIZER TANKS (NO.= 1)                          67.84
 (ELLIPSOIDAL)
  DIAMETER=     3.413 M
  LENGTH  =     2.413 M
  VOLUME  =    14.713 M3
  AVG THK =    .00064 M
  FS = 1.50,  FNOP= 1.30

FUEL TANKS (NO.= 1)                              58.33
 (ELLIPSOIDAL)
  DIAMETER=     3.164 M
  LENGTH  =     2.238 M
  VOLUME  =    11.733 M3
  AVG THK =    .00064 M
  FS = 1.50,  FNOP= 1.30

PRESSURANT                                        8.755

PRESSURANT TANKS (NO.= 1)                        47.34
  DIA=     .7388 M
  VOL=      .211 M3
  THK=    .00623 M
  FS = 1.50,  FNOP= 1.10

FUEL TANK INSULATION                             26.18
OXIDIZER TANK INSULATION                         43.49

ENGINES (NO.= 1)                                 35.38

COMPONENTS AND LINES                            554.29
ENG. MOUNTS,SUPPORTS                           1322.22

TOTAL WET SYSTEM MASS                          23267.7
TOTAL BURNOUT MASS                              2881.5
   (INCL.NON-USABLE PROP. AND GAS)

MASS FRACTION                                     .863
TOTAL IMPULSE                              71254532.0 N-S

             PRESSURE SCHEDULE(N/M2  )   AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =   .2482E+08    INITIAL CHAMBER PRESSURE =0.
INITIAL OX SYS PRESSURE   =   .1517E+06    FINAL OX SYS PRESSURE    =  .1517E+06
INITIAL FU SYS PRESSURE   =   .1517E+06    FINAL FU SYS PRESSURE    =  .1517E+06
```

9 BURNS, CONSTANT ACCELERATION, T/M=0.01

LCH4/LO2 MAX PERF PUMP FED MR=3.7

VEHICLE MASS =27215.5 KG DELTA V= 4815.8 M/S AVE. ISP=3520.4 N-S/KG

TOTAL PROPELLANT		21184.19 KG
USABLE FUEL	4287.29	
USABLE OXIDIZER	15862.97	
FUEL TRAPPED	140.74	
OXID TRAPPED	578.87	
FUEL START-S/D LOSSES	15.42	
OXID START-S/D LOSSES	15.42	
FUEL BOILOFF	78.93	
OXIDIZER BOILOFF	204.54	
OXIDIZER TANKS (NO.= 1)		68.85
(ELLIPSOIDAL)		
DIAMETER= 3.438 M		
LENGTH = 2.431 M		
VOLUME = 15.045 M3		
AVG THK = .00064 M		
FS = 1.50, FNOP= 1.30		
FUEL TANKS (NO.= 1)		55.99
(ELLIPSOIDAL)		
DIAMETER= 3.100 M		
LENGTH = 2.192 M		
VOLUME = 11.032 M3		
AVG THK = .00064 M		
FS = 1.50, FNOP= 1.30		
PRESSURANT		8.670
PRESSURANT TANKS (NO.= 1)		46.89
DIA= .7364 M		
VOL= .209 M3		
THK= .00621 M		
FS = 1.50, FNOP= 1.10		
FUEL TANK INSULATION		25.13
OXIDIZER TANK INSULATION		44.14
ENGINES (NO.= 1)		35.38
COMPONENTS AND LINES		554.29
ENG. MOUNTS, SUPPORTS		1322.22
TOTAL WET SYSTEM MASS		23345.7
TOTAL BURNOUT MASS		2881.2
(INCL.NON-USABLE PROP. AND GAS)		
MASS FRACTION		.863
TOTAL IMPULSE		70940717.2 N-S

PRESSURE SCHEDULE(N/M2) AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =	.2482E+08	INITIAL CHAMBER PRESSURE =	0.
INITIAL OX SYS PRESSURE =	.1517E+06	FINAL OX SYS PRESSURE =	.1517E+06
INITIAL FU SYS PRESSURE =	.1517E+06	FINAL FU SYS PRESSURE =	.1517E+06

9 BURNS, CONSTANT ACCELERATION, T/M=0.01

```
   LCH4/LO2  MAX PERF  PUMP FED              MR=4.0

VEHICLE MASS  =27215.5 KG    DELTA V=  4815.8 M/S   AVE. ISP=3471.4 N-S/KG

TOTAL PROPELLANT                          21319.18 KG
  USABLE FUEL                    4056.40
  USABLE OXIDIZER               16225.60
  FUEL TRAPPED                    131.26
  OXID TRAPPED                    591.62
  FUEL START-S/D LOSSES            15.42
  OXID START-S/D LOSSES            15.42
  FUEL BOILOFF                     78.07
  OXIDIZER BOILOFF                205.37

OXIDIZER TANKS (NO.= 1)                      69.89
 (ELLIPSOIDAL)
  DIAMETER=     3.464 M
  LENGTH   =    2.449 M
  VOLUME   =   15.385 M3
  AVG THK  =   .00064 M
  FS = 1.50,  FNOP= 1.30

FUEL TANKS (NO.= 1)                          53.98
 (ELLIPSOIDAL)
  DIAMETER=     3.044 M
  LENGTH   =    2.152 M
  VOLUME   =   10.443 M3
  AVG THK  =   .00064 M
  FS = 1.50,  FNOP= 1.30

PRESSURANT                                   8.622

PRESSURANT TANKS (NO.= 1)                    46.63
  DIA=     .7351 M
  VOL=      .208 M3
  THK=    .00620 M
  FS = 1.50,  FNOP= 1.10

FUEL TANK INSULATION                         24.22
OXIDIZER TANK INSULATION                     44.80

ENGINES (NO.= 1)                             35.38

COMPONENTS AND LINES                        554.29
ENG. MOUNTS,SUPPORTS                       1322.22

TOTAL WET SYSTEM MASS                      23479.2
TOTAL BURNOUT MASS                          2882.9
   (INCL.NON-USABLE PROP. AND GAS)

MASS FRACTION                                 .864
TOTAL IMPULSE                           70410040.1 N-S

             PRESSURE SCHEDULE(N/M2  )   AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =   .2482E+08    INITIAL CHAMBER PRESSURE =0.
INITIAL OX SYS PRESSURE   =   .1517E+06    FINAL OX SYS PRESSURE    =  .1517E+06
INITIAL FU SYS PRESSURE   =   .1517E+06    FINAL FU SYS PRESSURE    =  .1517E+06
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9 BURNS, CONSTANT ACCELERATION, T/M=0.015

```
 LCH4/LO2   MAX PERF   PUMP FED                     MR=3.4

VEHICLE MASS   =27215.5 KG     DELTA V=  4480.6 M/S    AVE. ISP=3559.7 N-S/KG

TOTAL PROPELLANT                           20320.25 KG
  USABLE FUEL                    4399.21
  USABLE OXIDIZER               14957.32
  FUEL TRAPPED                    143.45
  OXID TRAPPED                    527.35
  FUEL START-S/D LOSSES             7.26
  OXID START-S/D LOSSES             7.26
  FUEL BOILOFF                     78.39
  OXIDIZER BOILOFF                200.01

OXIDIZER TANKS (NO.= 1)                       66.16
 (ELLIPSOIDAL)
  DIAMETER=     3.370 M
  LENGTH  =     2.383 M
  VOLUME  =    14.169 M3
  AVG THK =    .00064 M
  FS = 1.50,   FNOP= 1.30

FUEL TANKS (NO.= 1)                           56.86
 (ELLIPSOIDAL)
  DIAMETER=     3.124 M
  LENGTH  =     2.209 M
  VOLUME  =    11.290 M3
  AVG THK =    .00064 M
  FS = 1.50,   FNOP= 1.30

PRESSURANT                                     8.437

PRESSURANT TANKS (NO.= 1)                     45.62
  DIA=     .7298 M
  VOL=       .203 M3
  THK=    .00616 M
  FS = 1.50,   FNOP= 1.10

FUEL TANK INSULATION                          25.52
OXIDIZER TANK INSULATION                      42.41

ENGINES (NO.= 1)                              40.82

COMPONENTS AND LINES                         554.29
ENG. MOUNTS,SUPPORTS                        1307.25

TOTAL WET SYSTEM MASS                       22467.6
TOTAL BURNOUT MASS                           2818.2
   (INCL.NON-USABLE PROP. AND GAS)

MASS FRACTION                                  .862
TOTAL IMPULSE                            68905628.5 N-S

             PRESSURE SCHEDULE(N/M2   )    AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =   .2482E+08    INITIAL CHAMBER PRESSURE =0.
INITIAL OX SYS PRESSURE   =   .1517E+06    FINAL OX SYS PRESSURE    =  .1517E+06
INITIAL FU SYS PRESSURE   =   .1517E+06    FINAL FU SYS PRESSURE    =  .1517E+06
```

9 BURNS, CONSTANT ACCELERATION, T/M=0.015

LCH4/LO2 MAX PERF PUMP FED MR=3.7

VEHICLE MASS =27215.5 KG DELTA V= 4480.6 M/S AVE. ISP=3540.0 N-S/KG

TOTAL PROPELLANT		20374.81 KG
USABLE FUEL	4129.79	
USABLE OXIDIZER	15280.24	
FUEL TRAPPED	132.53	
OXID TRAPPED	539.57	
FUEL START-S/D LOSSES	7.26	
OXID START-S/D LOSSES	7.26	
FUEL BOILOFF	77.41	
OXIDIZER BOILOFF	200.76	
OXIDIZER TANKS (NO.= 1)		67.10
(ELLIPSOIDAL)		
DIAMETER= 3.394 M		
LENGTH = 2.400 M		
VOLUME = 14.473 M3		
AVG THK = .00064 M		
FS = 1.50, FNOP= 1.30		
FUEL TANKS (NO.= 1)		54.53
(ELLIPSOIDAL)		
DIAMETER= 3.060 M		
LENGTH = 2.163 M		
VOLUME = 10.604 M3		
AVG THK = .00064 M		
FS = 1.50, FNOP= 1.30		
PRESSURANT		8.346
PRESSURANT TANKS (NO.= 1)		45.14
DIA= .7272 M		
VOL= .201 M3		
THK= .00614 M		
FS = 1.50, FNOP= 1.10		
FUEL TANK INSULATION		24.47
OXIDIZER TANK INSULATION		43.01
ENGINES (NO.= 1)		40.82
COMPONENTS AND LINES		554.29
ENG. MOUNTS, SUPPORTS		1307.25
TOTAL WET SYSTEM MASS		22519.8
TOTAL BURNOUT MASS		2817.1
(INCL.NON-USABLE PROP. AND GAS)		
MASS FRACTION		.862
TOTAL IMPULSE		68715377.9 N-S

PRESSURE SCHEDULE(N/M2) AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =	.2482E+08	INITIAL CHAMBER PRESSURE =	0.
INITIAL OX SYS PRESSURE =	.1517E+06	FINAL OX SYS PRESSURE =	.1517E+06
INITIAL FU SYS PRESSURE =	.1517E+06	FINAL FU SYS PRESSURE =	.1517E+06

9 BURNS, CONSTANT ACCELERATION, T/M=0.015

LCH4/LO2 MAX PERF PUMP FED MR=4.0

VEHICLE MASS =27215.5 KG DELTA V= 4480.6 M/S AVE. ISP=3491.0 N-S/KG

TOTAL PROPELLANT		20512.50 KG
USABLE FUEL	3908.88	
USABLE OXIDIZER	15635.51	
FUEL TRAPPED	123.76	
OXID TRAPPED	551.68	
FUEL START-S/D LOSSES	7.26	
OXID START-S/D LOSSES	7.26	
FUEL BOILOFF	76.59	
OXIDIZER BOILOFF	201.57	
OXIDIZER TANKS (NO.= 1)		68.12
(ELLIPSOIDAL)		
DIAMETER= 3.420 M		
LENGTH = 2.418 M		
VOLUME = 14.805 M3		
AVG THK = .00064 M		
FS = 1.50, FNOP= 1.30		
FUEL TANKS (NO.= 1)		52.59
(ELLIPSOIDAL)		
DIAMETER= 3.004 M		
LENGTH = 2.124 M		
VOLUME = 10.041 M3		
AVG THK = .00064 M		
FS = 1.50, FNOP= 1.30		
PRESSURANT		8.303
PRESSURANT TANKS (NO.= 1)		44.90
DIA= .7259 M		
VOL= .200 M3		
THK= .00612 M		
FS = 1.50, FNOP= 1.10		
FUEL TANK INSULATION		23.60
OXIDIZER TANK INSULATION		43.67
ENGINES (NO.= 1)		40.82
COMPONENTS AND LINES		554.29
ENG. MOUNTS,SUPPORTS		1307.25
TOTAL WET SYSTEM MASS		22656.1
TOTAL BURNOUT MASS		2819.0
(INCL.NON-USABLE PROP. AND GAS)		
MASS FRACTION		.863
TOTAL IMPULSE		68232717.0 N-S

PRESSURE SCHEDULE(N/M2) AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =	.2482E+08	INITIAL CHAMBER PRESSURE =	0.
INITIAL OX SYS PRESSURE =	.1517E+06	FINAL OX SYS PRESSURE =	.1517E+06
INITIAL FU SYS PRESSURE =	.1517E+06	FINAL FU SYS PRESSURE =	.1517E+06

9 BURNS, CONSTANT ACCELERATION, T/M=0.05

LCH4/LO2 MAX PERF PUMP FED MR=3.7

VEHICLE MASS =27215.5 KG DELTA V= 4303.8 M/S AVE. ISP=3608.7 N-S/KG

TOTAL PROPELLANT		19816.36 KG
USABLE FUEL	4006.98	
USABLE OXIDIZER	14825.83	
FUEL TRAPPED	148.50	
OXID TRAPPED	540.48	
FUEL START-S/D LOSSES	7.26	
OXID START-S/D LOSSES	7.26	
FUEL BOILOFF	77.93	
OXIDIZER BOILOFF	202.12	
OXIDIZER TANKS (NO.= 1) (ELLIPSOIDAL)		75.96
DIAMETER= 3.362 M		
LENGTH = 2.377 M		
VOLUME = 14.064 M3		
AVG THK = .00064 M		
FS = 1.50, FNOP= 1.50		
FUEL TANKS (NO.= 1) (ELLIPSOIDAL)		53.64
DIAMETER= 3.034 M		
LENGTH = 2.146 M		
VOLUME = 10.344 M3		
AVG THK = .00064 M		
FS = 1.50, FNOP= 1.30		
PRESSURANT		8.103
PRESSURANT TANKS (NO.= 1)		43.82
DIA= .7200 M		
VOL= .195 M3		
THK= .00608 M		
FS = 1.50, FNOP= 1.10		
FUEL TANK INSULATION		24.07
OXIDIZER TANK INSULATION		42.20
ENGINES (NO.= 1)		64.41
COMPONENTS AND LINES		554.29
ENG. MOUNTS, SUPPORTS		1318.59
TOTAL WET SYSTEM MASS		22001.4
TOTAL BURNOUT MASS (INCL.NON-USABLE PROP. AND GAS)		2874.1
MASS FRACTION		.856
TOTAL IMPULSE		67964694.8 N-S

PRESSURE SCHEDULE(N/M2) AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =	.2482E+08	INITIAL CHAMBER PRESSURE =	0.
INITIAL OX SYS PRESSURE =	.1517E+06	FINAL OX SYS PRESSURE =	.1517E+06
INITIAL FU SYS PRESSURE =	.1517E+06	FINAL FU SYS PRESSURE =	.1517E+06

9 BURNS, CONSTANT ACCELERATION, T/M=0.1

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LCH4/LO2  MAX PERF  PUMP FED               MR=3.4

VEHICLE MASS  =27215.5 KG    DELTA V=  4291.6 M/S   AVE. ISP=3647.9 N-S/KG

TOTAL PROPELLANT                          19632.15 KG
  USABLE FUEL                   4249.81
  USABLE OXIDIZER              14449.36
  FUEL TRAPPED                   138.22
  OXID TRAPPED                   507.75
  FUEL START-S/D LOSSES            6.80
  OXID START-S/D LOSSES            6.80
  FUEL BOILOFF                    76.95
  OXIDIZER BOILOFF               196.45

OXIDIZER TANKS (NO.= 1)                      64.65
 (ELLIPSOIDAL)
  DIAMETER=     3.331 M
  LENGTH   =    2.356 M
  VOLUME   =   13.689 M3
  AVG THK  =   .00064 M
  FS = 1.50,  FNOP= 1.30

FUEL TANKS (NO.= 1)                          55.57
 (ELLIPSOIDAL)
  DIAMETER=     3.089 M
  LENGTH   =    2.184 M
  VOLUME   =   10.908 M3
  AVG THK  =   .00064 M
  FS = 1.50,  FNOP= 1.30

PRESSURANT                                    8.152

PRESSURANT TANKS (NO.= 1)                    44.08
  DIA=     .7215 M
  VOL=      .197 M3
  THK=    .00609 M
  FS = 1.50,  FNOP= 1.10

FUEL TANK INSULATION                         24.94
OXIDIZER TANK INSULATION                     41.45

ENGINES (NO.= 1)                             93.44

COMPONENTS AND LINES                        554.29
ENG. MOUNTS,SUPPORTS                       1301.81

TOTAL WET SYSTEM MASS                      21820.5
TOTAL BURNOUT MASS                          2834.4
   (INCL.NON-USABLE PROP. AND GAS)

MASS FRACTION                                 .857
TOTAL IMPULSE                          68215933.8 N-S

             PRESSURE SCHEDULE(N/M2  )   AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =   .2482E+08    INITIAL CHAMBER PRESSURE =0.
INITIAL OX SYS PRESSURE   =   .1517E+06    FINAL OX SYS PRESSURE    =  .1517E+06
INITIAL FU SYS PRESSURE   =   .1517E+06    FINAL FU SYS PRESSURE    =  .1517E+06
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9 BURNS, CONSTANT ACCELERATION, T/M=0.1

LCH4/LO2 MAX PERF PUMP FED MR=3.7

VEHICLE MASS =27215.5 KG DELTA V= 4291.6 M/S AVE. ISP=3618.5 N-S/KG

TOTAL PROPELLANT		19713.39 KG
USABLE FUEL	3995.45	
USABLE OXIDIZER	14783.17	
FUEL TRAPPED	127.69	
OXID TRAPPED	520.23	
FUEL START-S/D LOSSES	6.80	
OXID START-S/D LOSSES	6.80	
FUEL BOILOFF	76.01	
OXIDIZER BOILOFF	197.22	
OXIDIZER TANKS (NO.= 1)		65.64
(ELLIPSOIDAL)		
DIAMETER= 3.357 M		
LENGTH = 2.374 M		
VOLUME = 14.003 M3		
AVG THK = .00064 M		
FS = 1.50, FNOP= 1.30		
FUEL TANKS (NO.= 1)		53.34
(ELLIPSOIDAL)		
DIAMETER= 3.026 M		
LENGTH = 2.140 M		
VOLUME = 10.260 M3		
AVG THK = .00064 M		
FS = 1.50, FNOP= 1.30		
PRESSURANT		8.076
PRESSURANT TANKS (NO.= 1)		43.68
DIA= .7192 M		
VOL= .195 M3		
THK= .00607 M		
FS = 1.50, FNOP= 1.10		
FUEL TANK INSULATION		23.94
OXIDIZER TANK INSULATION		42.08
ENGINES (NO.= 1)		93.44
COMPONENTS AND LINES		554.29
ENG. MOUNTS, SUPPORTS		1301.81
TOTAL WET SYSTEM MASS		21899.7
TOTAL BURNOUT MASS		2834.2
(INCL. NON-USABLE PROP. AND GAS)		
MASS FRACTION		.857
TOTAL IMPULSE		67953323.0 N-S

PRESSURE SCHEDULE(N/M2) AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =	.2482E+08	INITIAL CHAMBER PRESSURE =	0.
INITIAL OX SYS PRESSURE =	.1517E+06	FINAL OX SYS PRESSURE =	.1517E+06
INITIAL FU SYS PRESSURE =	.1517E+06	FINAL FU SYS PRESSURE =	.1517E+06

9 BURNS, CONSTANT ACCELERATION, T/M=0.1

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    LCH4/LO2  MAX PERF  PUMP FED              MR=4.0

VEHICLE MASS  =27215.5 KG    DELTA V=  4291.6 M/S   AVE. ISP=3569.5 N-S/KG

TOTAL PROPELLANT                              19850.16 KG
  USABLE FUEL                      3782.41
  USABLE OXIDIZER                 15129.66
  FUEL TRAPPED                      119.12
  OXID TRAPPED                      532.12
  FUEL START-S/D LOSSES               6.80
  OXID START-S/D LOSSES               6.80
  FUEL BOILOFF                       75.22
  OXIDIZER BOILOFF                  198.02

OXIDIZER TANKS (NO.= 1)                          66.65
 (ELLIPSOIDAL)
  DIAMETER=     3.382 M
  LENGTH  =     2.392 M
  VOLUME  =    14.327 M3
  AVG THK =    .00064 M
  FS = 1.50,  FNOP= 1.30

FUEL TANKS (NO.= 1)                              51.45
 (ELLIPSOIDAL)
  DIAMETER=     2.972 M
  LENGTH  =     2.101 M
  VOLUME  =     9.717 M3
  AVG THK =    .00064 M
  FS = 1.50,  FNOP= 1.30

PRESSURANT                                        8.035

PRESSURANT TANKS (NO.= 1)                        43.46
  DIA=     .7180 M
  VOL=      .194 M3
  THK=    .00606 M
  FS = 1.50,  FNOP= 1.10

FUEL TANK INSULATION                             23.09
OXIDIZER TANK INSULATION                         42.73

ENGINES (NO.= 1)                                 93.44

COMPONENTS AND LINES                            554.29
ENG. MOUNTS,SUPPORTS                           1301.81

TOTAL WET SYSTEM MASS                          22035.1
TOTAL BURNOUT MASS                              2836.2
   (INCL.NON-USABLE PROP. AND GAS)

MASS FRACTION                                     .858
TOTAL IMPULSE                               67508902.6 N-S

            PRESSURE SCHEDULE(N/M2  )    AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =   .2482E+08    INITIAL CHAMBER PRESSURE =0.
INITIAL OX SYS PRESSURE   =   .1517E+06    FINAL OX SYS PRESSURE    =  .1517E+06
INITIAL FU SYS PRESSURE   =   .1517E+06    FINAL FU SYS PRESSURE    =  .1517E+06
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9 BURNS, CONSTANT ACCELERATION, T/M=0.01

LCH4/LO2 MIN LENGTH PUMP FED MR=3.4

VEHICLE MASS =27215.5 KG DELTA V= 4815.8 M/S AVE. ISP=3549.8 N-S/KG

TOTAL PROPELLANT		21147.64	KG
USABLE FUEL	4559.08		
USABLE OXIDIZER	15500.86		
FUEL TRAPPED	158.62		
OXID TRAPPED	594.95		
FUEL START-S/D LOSSES	15.42		
OXID START-S/D LOSSES	15.42		
FUEL BOILOFF	79.94		
OXIDIZER BOILOFF	223.35		
OXIDIZER TANKS (NO.= 1) (TOROIDAL)		106.61	
INNER DIA= 1.349 M			
OUTER DIA= 4.267 M			
HEIGHT = 1.459 M			
VOLUME = 14.750 M3			
AVG THK = .00064 M			
FS = 1.50, FNOP= 1.50			
FUEL TANKS (NO.= 1) (ELLIPSOIDAL)		58.36	
DIAMETER= 3.165 M			
LENGTH = 2.238 M			
VOLUME = 11.741 M3			
AVG THK = .00064 M			
FS = 1.50, FNOP= 1.30			
PRESSURANT		8.756	
PRESSURANT TANKS (NO.= 1)		47.34	
DIA= .7388 M			
VOL= .211 M3			
THK= .00623 M			
FS = 1.50, FNOP= 1.10			
FUEL TANK INSULATION		26.19	
OXIDIZER TANK INSULATION		59.23	
ENGINES (NO.= 1)		35.38	
COMPONENTS AND LINES		589.67	
ENG. MOUNTS,SUPPORTS		1304.99	
TOTAL WET SYSTEM MASS		23384.2	
TOTAL BURNOUT MASS (INCL.NON-USABLE PROP. AND GAS)		2990.1	
MASS FRACTION		.858	
TOTAL IMPULSE		71212900.9	N-S

PRESSURE SCHEDULE(N/M2) AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =	.2482E+08	INITIAL CHAMBER PRESSURE =	0.
INITIAL OX SYS PRESSURE =	.1517E+06	FINAL OX SYS PRESSURE =	.1517E+06
INITIAL FU SYS PRESSURE =	.1517E+06	FINAL FU SYS PRESSURE =	.1517E+06

9 BURNS, CONSTANT ACCELERATION, T/M=0.01

LCH4/LO2 MIN LENGTH PUMP FED MR=3.7

VEHICLE MASS =27215.5 KG DELTA V= 4815.8 M/S AVE. ISP=3520.4 N-S/KG

TOTAL PROPELLANT		21227.81 KG
USABLE FUEL	4284.82	
USABLE OXIDIZER	15853.84	
FUEL TRAPPED	145.76	
OXID TRAPPED	609.74	
FUEL START-S/D LOSSES	15.42	
OXID START-S/D LOSSES	15.42	
FUEL BOILOFF	78.94	
OXIDIZER BOILOFF	223.88	
OXIDIZER TANKS (NO.= 1)		107.38
(TOROIDAL)		
INNER DIA= 1.305 M		
OUTER DIA= 4.267 M		
HEIGHT = 1.481 M		
VOLUME = 15.082 M3		
AVG THK = .00064 M		
FS = 1.50, FNOP= 1.50		
FUEL TANKS (NO.= 1)		56.01
(ELLIPSOIDAL)		
DIAMETER= 3.101 M		
LENGTH = 2.193 M		
VOLUME = 11.038 M3		
AVG THK = .00064 M		
FS = 1.50, FNOP= 1.30		
PRESSURANT		8.671
PRESSURANT TANKS (NO.= 1)		46.89
DIA= .7365 M		
VOL= .209 M3		
THK= .00621 M		
FS = 1.50, FNOP= 1.10		
FUEL TANK INSULATION		25.13
OXIDIZER TANK INSULATION		59.66
ENGINES (NO.= 1)		35.38
COMPONENTS AND LINES		589.67
ENG. MOUNTS,SUPPORTS		1304.99
TOTAL WET SYSTEM MASS		23461.6
TOTAL BURNOUT MASS		2989.3
(INCL.NON-USABLE PROP. AND GAS)		
MASS FRACTION		.858
TOTAL IMPULSE		70899867.9 N-S

PRESSURE SCHEDULE(N/M2) AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =	.2482E+08	INITIAL CHAMBER PRESSURE =	0.
INITIAL OX SYS PRESSURE =	.1517E+06	FINAL OX SYS PRESSURE =	.1517E+06
INITIAL FU SYS PRESSURE =	.1517E+06	FINAL FU SYS PRESSURE =	.1517E+06

9 BURNS, CONSTANT ACCELERATION, T/M=0.01

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   LCH4/LO2  MIN LENGTH  PUMP FED             MR4.0

VEHICLE MASS  =27215.5 KG    DELTA V=  4815.8 M/S   AVE. ISP=3471.4 N-S/KG

TOTAL PROPELLANT                              21362.60 KG
  USABLE FUEL                      4054.10
  USABLE OXIDIZER                 16216.40
  FUEL TRAPPED                      135.36
  OXID TRAPPED                      623.40
  FUEL START-S/D LOSSES              15.42
  OXID START-S/D LOSSES              15.42
  FUEL BOILOFF                       78.08
  OXIDIZER BOILOFF                  224.41

OXIDIZER TANKS (NO.= 1)                         108.51
 (TOROIDAL)
  INNER DIA=     1.259 M
  OUTER DIA=     4.267 M
  HEIGHT   =     1.504 M
  VOLUME   =.   15.422 M3
  AVG THK  =    .00064 M
  FS = 1.50,  FNOP= 1.50

FUEL TANKS (NO.= 1)                              53.99
 (ELLIPSOIDAL)
  DIAMETER=     3.044 M
  LENGTH  =     2.153 M
  VOLUME  =    10.448 M3
  AVG THK =    .00064 M
  FS = 1.50,  FNOP= 1.30

PRESSURANT                                       8.623

PRESSURANT TANKS (NO.= 1)                        46.63
  DIA=     .7351 M
  VOL=      .208 M3
  THK=    .00620 M
  FS = 1.50,  FNOP= 1.10

FUEL TANK INSULATION                             24.23
OXIDIZER TANK INSULATION                         60.08

ENGINES (NO.= 1)                                 35.38

COMPONENTS AND LINES                            589.67
ENG. MOUNTS,SUPPORTS                           1304.99

TOTAL WET SYSTEM MASS                          23594.7
TOTAL BURNOUT MASS                              2990.9
   (INCL.NON-USABLE PROP. AND GAS)

MASS FRACTION                                     .859
TOTAL IMPULSE                             70370128.5 N-S

             PRESSURE SCHEDULE(N/M2  )   AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =   .2482E+08    INITIAL CHAMBER PRESSURE =0.
INITIAL OX SYS PRESSURE   =   .1517E+06    FINAL OX SYS PRESSURE    =  .1517E+06
INITIAL FU SYS PRESSURE   =   .1517E+06    FINAL FU SYS PRESSURE    =  .1517E+06
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9 BURNS, CONSTANT ACCELERATION, T/M=0.015

LCH4/LO2 MIN LENGTH PUMP FED MR=3.4

VEHICLE MASS =27215.5 KG DELTA V= 4480.6 M/S AVE. ISP=3559.7 N-S/KG

TOTAL PROPELLANT		20382.31 KG
USABLE FUEL	4396.58	
USABLE OXIDIZER	14948.37	
FUEL TRAPPED	152.57	
OXID TRAPPED	571.90	
FUEL START-S/D LOSSES	7.26	
OXID START-S/D LOSSES	7.26	
FUEL BOILOFF	78.41	
OXIDIZER BOILOFF	219.96	
OXIDIZER TANKS (NO.= 1)		105.34
(TOROIDAL)		
INNER DIA= 1.420 M		
OUTER DIA= 4.267 M		
HEIGHT = 1.424 M		
VOLUME = 14.220 M3		
AVG THK = .00064 M		
FS = 1.50, FNOP= 1.50		
FUEL TANKS (NO.= 1)		56.91
(ELLIPSOIDAL)		
DIAMETER= 3.126 M		
LENGTH = 2.210 M		
VOLUME = 11.306 M3		
AVG THK = .00064 M		
FS = 1.50, FNOP= 1.30		
PRESSURANT		8.439
PRESSURANT TANKS (NO.= 1)		45.63
DIA= .7298 M		
VOL= .204 M3		
THK= .00616 M		
FS = 1.50, FNOP= 1.10		
FUEL TANK INSULATION		25.54
OXIDIZER TANK INSULATION		58.52
ENGINES (NO.= 1)		40.82
COMPONENTS AND LINES		589.67
ENG. MOUNTS,SUPPORTS		1293.65
TOTAL WET SYSTEM MASS		22606.8
TOTAL BURNOUT MASS		2949.0
(INCL.NON-USABLE PROP. AND GAS)		
MASS FRACTION		.856
TOTAL IMPULSE		68864404.4 N-S

PRESSURE SCHEDULE(N/M2) AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =	.2482E+08	INITIAL CHAMBER PRESSURE =	0.
INITIAL OX SYS PRESSURE =	.1517E+06	FINAL OX SYS PRESSURE =	.1517E+06
INITIAL FU SYS PRESSURE =	.1517E+06	FINAL FU SYS PRESSURE =	.1517E+06

9 BURNS, CONSTANT ACCELERATION, T/M=0.015

LCH4/LO2 MIN LENGTH PUMP FED MR=3.7

VEHICLE MASS =27215.5 KG DELTA V= 4480.6 M/S AVE. ISP=3540.0 N-S/KG

TOTAL PROPELLANT		20436.73 KG
USABLE FUEL	4127.35	
USABLE OXIDIZER	15271.21	
FUEL TRAPPED	140.28	
OXID TRAPPED	585.48	
FUEL START-S/D LOSSES	7.26	
OXID START-S/D LOSSES	7.26	
FUEL BOILOFF	77.43	
OXIDIZER BOILOFF	220.47	
OXIDIZER TANKS (NO.= 1) (TOROIDAL)		106.08
INNER DIA= 1.379 M		
OUTER DIA= 4.267 M		
HEIGHT = 1.444 M		
VOLUME = 14.524 M3		
AVG THK = .00064 M		
FS = 1.50, FNOP= 1.50		
FUEL TANKS (NO.= 1) (ELLIPSOIDAL)		54.57
DIAMETER= 3.061 M		
LENGTH = 2.164 M		
VOLUME = 10.617 M3		
AVG THK = .00064 M		
FS = 1.50, FNOP= 1.30		
PRESSURANT		8.348
PRESSURANT TANKS (NO.= 1)		45.14
DIA= .7272 M		
VOL= .201 M3		
THK= .00614 M		
FS = 1.50, FNOP= 1.10		
FUEL TANK INSULATION		24.49
OXIDIZER TANK INSULATION		58.93
ENGINES (NO.= 1)		40.82
COMPONENTS AND LINES		589.67
ENG. MOUNTS, SUPPORTS		1293.65
TOTAL WET SYSTEM MASS		22658.4
TOTAL BURNOUT MASS (INCL.NON-USABLE PROP. AND GAS)		2947.5
MASS FRACTION		.856
TOTAL IMPULSE		68674765.0 N-S

PRESSURE SCHEDULE(N/M2) AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =	.2482E+08	INITIAL CHAMBER PRESSURE =	0.
INITIAL OX SYS PRESSURE =	.1517E+06	FINAL OX SYS PRESSURE =	.1517E+06
INITIAL FU SYS PRESSURE =	.1517E+06	FINAL FU SYS PRESSURE =	.1517E+06

9 BURNS, CONSTANT ACCELERATION, T/M=0.05

LCH4/LO2 MIN LENGTH PUMP FED MR=3.7

VEHICLE MASS =27215.5 KG DELTA V= 4303.8 M/S AVE. ISP=3608.7 N-S/KG

TOTAL PROPELLANT		19831.45 KG
USABLE FUEL	4004.58	
USABLE OXIDIZER	14816.96	
FUEL TRAPPED	138.52	
OXID TRAPPED	540.39	
FUEL START-S/D LOSSES	15.42	
OXID START-S/D LOSSES	15.42	
FUEL BOILOFF	77.92	
OXIDIZER BOILOFF	222.23	
OXIDIZER TANKS (NO.= 1) (TOROIDAL)		105.00
INNER DIA= 1.438 M		
OUTER DIA= 4.267 M		
HEIGHT = 1.414 M		
VOLUME = 14.082 M3		
AVG THK = .00064 M		
FS = 1.50, FNOP= 1.50		
FUEL TANKS (NO.= 1) (ELLIPSOIDAL)		53.60
DIAMETER= 3.033 M		
LENGTH = 2.145 M		
VOLUME = 10.334 M3		
AVG THK = .00064 M		
FS = 1.50, FNOP= 1.30		
PRESSURANT		8.112
PRESSURANT TANKS (NO.= 1)		43.87
DIA= .7203 M		
VOL= .196 M3		
THK= .00608 M		
FS = 1.50, FNOP= 1.10		
FUEL TANK INSULATION		24.05
OXIDIZER TANK INSULATION		58.33
ENGINES (NO.= 1)		64.41
COMPONENTS AND LINES		589.67
ENG. MOUNTS, SUPPORTS		1356.24
TOTAL WET SYSTEM MASS		22134.7
TOTAL BURNOUT MASS (INCL.NON-USABLE PROP. AND GAS)		2982.2
MASS FRACTION		.850
TOTAL IMPULSE		67924062.4 N-S

PRESSURE SCHEDULE(N/M2) AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =	.2482E+08	INITIAL CHAMBER PRESSURE =	0.
INITIAL OX SYS PRESSURE =	.1517E+06	FINAL OX SYS PRESSURE =	.1517E+06
INITIAL FU SYS PRESSURE =	.1517E+06	FINAL FU SYS PRESSURE =	.1517E+06

9 BURNS, CONSTANT ACCELERATION, T/M=0.015

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   LCH4/LO2  MIN LENGTH  PUMP FED                  MR=4.0

VEHICLE MASS  =27215.5 KG    DELTA V=  4480.6 M/S   AVE. ISP=3491.0 N-S/KG

TOTAL PROPELLANT                          20573.78 KG
  USABLE FUEL                   3906.60
  USABLE OXIDIZER              15626.40
  FUEL TRAPPED                   130.14
  OXID TRAPPED                   598.50
  FUEL START-S/D LOSSES            7.26
  OXID START-S/D LOSSES            7.26
  FUEL BOILOFF                    76.60
  OXIDIZER BOILOFF               221.01

OXIDIZER TANKS (NO.= 1)                     106.86
 (TOROIDAL)
  INNER DIA=     1.335 M
  OUTER DIA=     4.267 M
  HEIGHT   =     1.466 M
  VOLUME   =    14.857 M3
  AVG THK  =    .00064 M
  FS = 1.50,  FNOP= 1.50

FUEL TANKS (NO.= 1)                          52.62
 (ELLIPSOIDAL)
  DIAMETER=     3.005 M
  LENGTH  =     2.125 M
  VOLUME  =    10.052 M3
  AVG THK =    .00064 M
  FS = 1.50,  FNOP= 1.30

PRESSURANT                                    8.304

PRESSURANT TANKS (NO.= 1)                    44.91
  DIA=     .7259 M
  VOL=      .200 M3
  THK=    .00613 M
  FS = 1.50,  FNOP= 1.10

FUEL TANK INSULATION                         23.61
OXIDIZER TANK INSULATION                     59.37

ENGINES (NO.= 1)                             40.82

COMPONENTS AND LINES                        589.67
ENG. MOUNTS,SUPPORTS                       1293.65

TOTAL WET SYSTEM MASS                      22793.6
TOTAL BURNOUT MASS                          2948.5
   (INCL.NON-USABLE PROP. AND GAS)

MASS FRACTION                                 .857
TOTAL IMPULSE                           68192954.0 N-S

             PRESSURE SCHEDULE(N/M2  )   AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =   .2482E+08    INITIAL CHAMBER PRESSURE =0.
INITIAL OX SYS PRESSURE   =   .1517E+06    FINAL OX SYS PRESSURE    =  .1517E+06
INITIAL FU SYS PRESSURE   =   .1517E+06    FINAL FU SYS PRESSURE    =  .1517E+06
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9 BURNS, CONSTANT ACCELERATION, T/M=0.1

LCH4/LO2 MIN LENGTH PUMP FED MR=3.4

VEHICLE MASS =27215.5 KG DELTA V= 4291.6 M/S AVE. ISP=3647.9 N-S/KG

TOTAL PROPELLANT		19691.90 KG
USABLE FUEL	4247.22	
USABLE OXIDIZER	14440.56	
FUEL TRAPPED	146.89	
OXID TRAPPED	550.02	
FUEL START-S/D LOSSES	6.80	
OXID START-S/D LOSSES	6.80	
FUEL BOILOFF	76.97	
OXIDIZER BOILOFF	216.63	
OXIDIZER TANKS (NO.= 1)		104.12
(TOROIDAL)		
INNER DIA= 1.484 M		
OUTER DIA= 4.267 M		
HEIGHT = 1.391 M		
VOLUME = 13.738 M3		
AVG THK = .00064 M		
FS = 1.50, FNOP= 1.50		
FUEL TANKS (NO.= 1)		55.62
(ELLIPSOIDAL)		
DIAMETER= 3.090 M		
LENGTH = 2.185 M		
VOLUME = 10.923 M3		
AVG THK = .00064 M		
FS = 1.50, FNOP= 1.30		
PRESSURANT		8.154
PRESSURANT TANKS (NO.= 1)		44.09
DIA= .7215 M		
VOL= .197 M3		
THK= .00609 M		
FS = 1.50, FNOP= 1.10		
FUEL TANK INSULATION		24.96
OXIDIZER TANK INSULATION		57.85
ENGINES (NO.= 1)		93.44
COMPONENTS AND LINES		589.67
ENG. MOUNTS, SUPPORTS		1284.12
TOTAL WET SYSTEM MASS		21953.9
TOTAL BURNOUT MASS		2958.9
(INCL.NON-USABLE PROP. AND GAS)		
MASS FRACTION		.851
TOTAL IMPULSE		68174398.2 N-S

PRESSURE SCHEDULE(N/M2) AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =	.2482E+08	INITIAL CHAMBER PRESSURE =	0.
INITIAL OX SYS PRESSURE =	.1517E+06	FINAL OX SYS PRESSURE =	.1517E+06
INITIAL FU SYS PRESSURE =	.1517E+06	FINAL FU SYS PRESSURE =	.1517E+06

9 BURNS, CONSTANT ACCELERATION, T/M=0.1

LCH4/LO2 MIN LENGTH PUMP FED MR=3.7

VEHICLE MASS =27215.5 KG DELTA V= 4291.6 M/S AVE. ISP=3618.5 N-S/KG

TOTAL PROPELLANT		19772.99 KG
USABLE FUEL	3993.05	
USABLE OXIDIZER	14774.28	
FUEL TRAPPED	134.98	
OXID TRAPPED	563.87	
FUEL START-S/D LOSSES	6.80	
OXID START-S/D LOSSES	6.80	
FUEL BOILOFF	76.03	
OXIDIZER BOILOFF	217.17	

OXIDIZER TANKS (NO.= 1) 104.92
(TOROIDAL)
INNER DIA= 1.442 M
OUTER DIA= 4.267 M
HEIGHT = 1.412 M
VOLUME = 14.052 M3
AVG THK = .00064 M
FS = 1.50, FNOP= 1.50

FUEL TANKS (NO.= 1) 53.39
(ELLIPSOIDAL)
DIAMETER= 3.027 M
LENGTH = 2.141 M
VOLUME = 10.272 M3
AVG THK = .00064 M
FS = 1.50, FNOP= 1.30

PRESSURANT 8.078

PRESSURANT TANKS (NO.= 1) 43.68
DIA= .7193 M
VOL= .195 M3
THK= .00607 M
FS = 1.50, FNOP= 1.10

FUEL TANK INSULATION 23.96
OXIDIZER TANK INSULATION 58.29

ENGINES (NO.= 1) 93.44

COMPONENTS AND LINES 589.67
ENG. MOUNTS, SUPPORTS 1284.12

TOTAL WET SYSTEM MASS 22032.5
TOTAL BURNOUT MASS 2958.4
(INCL.NON-USABLE PROP. AND GAS)

MASS FRACTION .852
TOTAL IMPULSE 67912424.3 N-S

PRESSURE SCHEDULE(N/M2) AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =	.2482E+08	INITIAL CHAMBER PRESSURE =	0.
INITIAL OX SYS PRESSURE =	.1517E+06	FINAL OX SYS PRESSURE =	.1517E+06
INITIAL FU SYS PRESSURE =	.1517E+06	FINAL FU SYS PRESSURE =	.1517E+06

9 BURNS, CONSTANT ACCELERATION, T/M=0.1

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    LCH4/LO2  MIN LENGTH  PUMP FED              MR=4.0

VEHICLE MASS  =27215.5 KG    DELTA V=  4291.6 M/S   AVE. ISP=3569.5 N-S/KG

TOTAL PROPELLANT                              19907.29 KG
  USABLE FUEL                       3780.17
  USABLE OXIDIZER                  15120.67
  FUEL TRAPPED                       125.50
  OXID TRAPPED                       574.39
  FUEL START-S/D LOSSES                6.80
  OXID START-S/D LOSSES                6.80
  FUEL BOILOFF                        75.23
  OXIDIZER BOILOFF                   217.72

OXIDIZER TANKS (NO.= 1)                          105.72
 (TOROIDAL)
  INNER DIA=     1.399 M
  OUTER DIA=     4.267 M
  HEIGHT   =     1.434 M
  VOLUME   =    14.375 M3
  AVG THK  =    .00064 M
  FS = 1.50,   FNOP= 1.50

FUEL TANKS (NO.= 1)                               51.48
 (ELLIPSOIDAL)
  DIAMETER=     2.973 M
  LENGTH  =     2.102 M
  VOLUME  =     9.727 M3
  AVG THK =    .00064 M
  FS = 1.50,   FNOP= 1.30

PRESSURANT                                        8.037

PRESSURANT TANKS (NO.= 1)                         43.47
  DIA=     .7181 M
  VOL=      .194 M3
  THK=    .00606 M
  FS = 1.50,   FNOP= 1.10

FUEL TANK INSULATION                              23.10
OXIDIZER TANK INSULATION                          58.73

ENGINES (NO.= 1)                                  93.44

COMPONENTS AND LINES                             589.67
ENG. MOUNTS,SUPPORTS                            1284.12

TOTAL WET SYSTEM MASS                           22165.1
TOTAL BURNOUT MASS                               2957.7
   (INCL.NON-USABLE PROP. AND GAS)

MASS FRACTION                                      .853
TOTAL IMPULSE                              67468788.7 N-S

             PRESSURE SCHEDULE(N/M2   )   AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =   .2482E+08   INITIAL CHAMBER PRESSURE =0.
INITIAL OX SYS PRESSURE   =   .1517E+06   FINAL OX SYS PRESSURE    =  .1517E+06
INITIAL FU SYS PRESSURE   =   .1517E+06   FINAL FU SYS PRESSURE    =  .1517E+06
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9 BURNS, CONSTANT ACCELERATION, T/M=0.01

LH2/LO2 MAX PERF PRESS FED MR=5

VEHICLE MASS =27215.5 KG DELTA V= 4815.8 M/S AVE. ISP=4373.6 N-S/KG

TOTAL PROPELLANT		19066.74 KG
USABLE FUEL	3001.63	
USABLE OXIDIZER	15008.13	
FUEL TRAPPED	113.14	
OXID TRAPPED	552.39	
FUEL START-S/D LOSSES	15.42	
OXID START-S/D LOSSES	15.42	
FUEL BOILOFF	158.02	
OXIDIZER BOILOFF	202.58	

OXIDIZER TANKS (NO.= 1) 399.50
(ELLIPSOIDAL)
DIAMETER= 3.376 M
LENGTH = 2.387 M
VOLUME = 14.248 M3
AVG THK = .00382 M
FS = 1.50, FNOP= 1.30

FUEL TANKS (NO.= 1) 1420.13
(CYLINDRICAL/SQRT(2) ELLIPTICAL)
DIAMETER= 4.267 M
LENGTH = 4.384 M
VOLUME = 48.311 M3
DOME THK= .00514 M
CYL THK = .00852 M
FS = 1.50, FNOP= 1.30

PRESSURANT 148.780

PRESSURANT TANKS (NO.= 1) 799.34
DIA= 1.8954 M
VOL= 3.565 M3
THK= .01599 M
FS = 1.50, FNOP= 1.10

FUEL TANK INSULATION 113.80
OXIDIZER TANK INSULATION 42.57

ENGINES (NO.= 1) 36.29

COMPONENTS AND LINES 554.74
ENG. MOUNTS,SUPPORTS 1322.22

TOTAL WET SYSTEM MASS 23904.1
TOTAL BURNOUT MASS 5502.9
(INCL.NON-USABLE PROP. AND GAS)

MASS FRACTION .753
TOTAL IMPULSE 78770443.8 N-S

PRESSURE SCHEDULE(N/M2) AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =	.2482E+08	INITIAL CHAMBER PRESSURE =	0.
INITIAL OX SYS PRESSURE =	.1069E+07	FINAL OX SYS PRESSURE =	.1069E+07
INITIAL FU SYS PRESSURE =	.1138E+07	FINAL FU SYS PRESSURE =	.1138E+07

9 BURNS, CONSTANT ACCELERATION, T/M=0.01

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   LH2/LO2  MAX PERF  PRESS FED                MR=6

VEHICLE MASS  =27215.5 KG    DELTA V=  4815.8 M/S   AVE. ISP=4295.1 N-S/KG

TOTAL PROPELLANT                              19247.87 KG
  USABLE FUEL                       2598.67
  USABLE OXIDIZER                  15592.03
  FUEL TRAPPED                        97.91
  OXID TRAPPED                       572.07
  FUEL START-S/D LOSSES               15.42
  OXID START-S/D LOSSES               15.42
  FUEL BOILOFF                       152.42
  OXIDIZER BOILOFF                   203.93

OXIDIZER TANKS (NO.= 1)                         414.82
 (ELLIPSOIDAL)
  DIAMETER=     3.419 M
  LENGTH  =     2.417 M
  VOLUME  =    14.794 M3
  AVG THK =    .00387 M
  FS = 1.50,  FNOP= 1.30

FUEL TANKS (NO.= 1)                            1241.25
 (CYLINDRICAL/SQRT(2) ELLIPTICAL)
  DIAMETER=     4.267 M
  LENGTH  =     3.948 M
  VOLUME  =    42.085 M3
  DOME THK=    .00514 M
  CYL THK =    .00852 M
  FS = 1.50,  FNOP= 1.30

PRESSURANT                                      131.183

PRESSURANT TANKS (NO.= 1)                       704.37
  DIA=    1.8171 M
  VOL=     3.142 M3
  THK=    .01533 M
  FS = 1.50,  FNOP= 1.10

FUEL TANK INSULATION                            103.54
OXIDIZER TANK INSULATION                         43.65

ENGINES (NO.= 1)                                 34.02

COMPONENTS AND LINES                            554.74
ENG. MOUNTS,SUPPORTS                           1322.22

TOTAL WET SYSTEM MASS                          23797.7
TOTAL BURNOUT MASS                              5219.8
   (INCL.NON-USABLE PROP. AND GAS)

MASS FRACTION                                     .764
TOTAL IMPULSE                               78134701.1 N-S

            PRESSURE SCHEDULE(N/M2  )   AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =   .2482E+08   INITIAL CHAMBER PRESSURE =0.
INITIAL OX SYS PRESSURE   =   .1069E+07   FINAL OX SYS PRESSURE    =  .1069E+07
INITIAL FU SYS PRESSURE   =   .1138E+07   FINAL FU SYS PRESSURE    =  .1138E+07
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9 BURNS, CONSTANT ACCELERATION, T/M=0.01

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   LH2/LO2  MAX PERF  PRESS FED              MR=7

VEHICLE MASS  =27215.5 KG    DELTA V=  4815.8 M/S   AVE. ISP=4177.4 N-S/KG

TOTAL PROPELLANT                              19526.89 KG
  USABLE FUEL                        2308.20
  USABLE OXIDIZER                   16157.42
  FUEL TRAPPED                         86.92
  OXID TRAPPED                        589.91
  FUEL START-S/D LOSSES                15.42
  OXID START-S/D LOSSES                15.42
  FUEL BOILOFF                        148.38
  OXIDIZER BOILOFF                    205.21

OXIDIZER TANKS (NO.= 1)                          429.62
 (ELLIPSOIDAL)
  DIAMETER=     3.459 M
  LENGTH  =     2.446 M
  VOLUME  =    15.322 M3
  AVG THK =    .00391 M
  FS = 1.50,  FNOP= 1.30

FUEL TANKS (NO.= 1)                             1112.30
 (CYLINDRICAL/SQRT(2) ELLIPTICAL)
  DIAMETER=     4.267 M
  LENGTH  =     3.635 M
  VOLUME  =    37.596 M3
  DOME THK=    .00514 M
  CYL THK =    .00852 M
  FS = 1.50,  FNOP= 1.30

PRESSURANT                                      118.596

PRESSURANT TANKS (NO.= 1)                        636.42
  DIA=    1.7567 M
  VOL=     2.839 M3
  THK=    .01482 M
  FS = 1.50,  FNOP= 1.10

FUEL TANK INSULATION                              96.15
OXIDIZER TANK INSULATION                          44.68

ENGINES (NO.= 1)                                  31.75

COMPONENTS AND LINES                             554.74
ENG. MOUNTS,SUPPORTS                            1322.22

TOTAL WET SYSTEM MASS                           23873.4
TOTAL BURNOUT MASS                               5023.3
   (INCL.NON-USABLE PROP. AND GAS)

MASS FRACTION                                      .773
TOTAL IMPULSE                              77142541.0 N-S

             PRESSURE SCHEDULE(N/M2  )    AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =   .2482E+08    INITIAL CHAMBER PRESSURE =0.
INITIAL OX SYS PRESSURE   =   .1069E+07    FINAL OX SYS PRESSURE    =  .1069E+07
INITIAL FU SYS PRESSURE   =   .1138E+07    FINAL FU SYS PRESSURE    =  .1138E+07
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9 BURNS, CONSTANT ACCELERATION, T/M=0.015

LH2/LO2 MAX PERF PRESS FED MR=5

VEHICLE MASS =27215.5 KG DELTA V= 4480.6 M/S AVE. ISP=4383.4 N-S/KG

TOTAL PROPELLANT		18260.31 KG
USABLE FUEL	2879.08	
USABLE OXIDIZER	14395.41	
FUEL TRAPPED	104.90	
OXID TRAPPED	513.24	
FUEL START-S/D LOSSES	7.26	
OXID START-S/D LOSSES	7.26	
FUEL BOILOFF	154.45	
OXIDIZER BOILOFF	198.71	

OXIDIZER TANKS (NO.= 1) 382.69
(ELLIPSOIDAL)
DIAMETER= 3.328 M
LENGTH = 2.353 M
VOLUME = 13.648 M3
AVG THK = .00377 M
FS = 1.50, FNOP= 1.30

FUEL TANKS (NO.= 1) 1359.97
(CYLINDRICAL/SQRT(2) ELLIPTICAL)
DIAMETER= 4.267 M
LENGTH = 4.237 M
VOLUME = 46.217 M3
DOME THK= .00514 M
CYL THK = .00852 M
FS = 1.50, FNOP= 1.30

PRESSURANT 142.526

PRESSURANT TANKS (NO.= 1) 765.76
DIA= 1.8685 M
VOL= 3.415 M3
THK= .01577 M
FS = 1.50, FNOP= 1.10

FUEL TANK INSULATION	110.35
OXIDIZER TANK INSULATION	41.36
ENGINES (NO.= 1)	54.43
COMPONENTS AND LINES	554.74
ENG. MOUNTS,SUPPORTS	1307.25
TOTAL WET SYSTEM MASS	22979.4
TOTAL BURNOUT MASS (INCL.NON-USABLE PROP. AND GAS)	5337.2
MASS FRACTION	.752
TOTAL IMPULSE	75723939.4 N-S

PRESSURE SCHEDULE(N/M2) AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =	.2482E+08	INITIAL CHAMBER PRESSURE =	0.
INITIAL OX SYS PRESSURE =	.1069E+07	FINAL OX SYS PRESSURE =	.1069E+07
INITIAL FU SYS PRESSURE =	.1138E+07	FINAL FU SYS PRESSURE =	.1138E+07

9 BURNS, CONSTANT ACCELERATION, T/M=0.015

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    LH2/LO2  MAX PERF  PRESS FED                MR=6

VEHICLE MASS  =27215.5 KG    DELTA V=  4480.6 M/S   AVE. ISP=4304.9 N-S/KG

TOTAL PROPELLANT                           18442.05 KG
  USABLE FUEL                    2493.68
  USABLE OXIDIZER               14962.09
  FUEL TRAPPED                     91.03
  OXID TRAPPED                    531.58
  FUEL START-S/D LOSSES             7.26
  OXID START-S/D LOSSES             7.26
  FUEL BOILOFF                    149.13
  OXIDIZER BOILOFF                200.03

OXIDIZER TANKS (NO.= 1)                      397.54
 (ELLIPSOIDAL)
  DIAMETER=    3.371 M
  LENGTH  =    2.383 M
  VOLUME  =   14.178 M3
  AVG THK =   .00381 M
  FS = 1.50,  FNOP= 1.30

FUEL TANKS (NO.= 1)                         1189.20
 (CYLINDRICAL/SQRT(2) ELLIPTICAL)
  DIAMETER=    4.267 M
  LENGTH  =    3.822 M
  VOLUME  =   40.273 M3
  DOME THK=   .00514 M
  CYL THK =   .00852 M
  FS = 1.50,  FNOP= 1.30

PRESSURANT                                   125.702

PRESSURANT TANKS (NO.= 1)                    674.96
  DIA=    1.7915 M
  VOL=     3.010 M3
  THK=    .01512 M
  FS = 1.50,  FNOP= 1.10

FUEL TANK INSULATION                         100.56
OXIDIZER TANK INSULATION                      42.43

ENGINES (NO.= 1)                              49.90

COMPONENTS AND LINES                         554.74
ENG. MOUNTS,SUPPORTS                        1307.25

TOTAL WET SYSTEM MASS                       22884.3
TOTAL BURNOUT MASS                           5064.9
   (INCL.NON-USABLE PROP. AND GAS)

MASS FRACTION                                  .763
TOTAL IMPULSE                           75149127.7 N-S

             PRESSURE SCHEDULE(N/M2  )   AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =   .2482E+08   INITIAL CHAMBER PRESSURE =O.
INITIAL OX SYS PRESSURE   =   .1069E+07   FINAL OX SYS PRESSURE    =  .1069E+07
INITIAL FU SYS PRESSURE   =   .1138E+07   FINAL FU SYS PRESSURE    =  .1138E+07
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9 BURNS, CONSTANT ACCELERATION, T/M=0.015

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   LH2/LO2  MAX PERF  PRESS FED                    MR=7

VEHICLE MASS  =27215.5 KG    DELTA V=  4480.6 M/S   AVE. ISP=4187.2 N-S/KG

TOTAL PROPELLANT                            18722.49 KG
  USABLE FUEL                     2216.48
  USABLE OXIDIZER                15515.39
  FUEL TRAPPED                      80.83
  OXID TRAPPED                     548.66
  FUEL START-S/D LOSSES              7.26
  OXID START-S/D LOSSES              7.26
  FUEL BOILOFF                     145.31
  OXIDIZER BOILOFF                 201.30

OXIDIZER TANKS (NO.= 1)                        412.01
 (ELLIPSOIDAL)
  DIAMETER=    3.411 M
  LENGTH  =    2.412 M
  VOLUME  =   14.694 M3
  AVG THK =   .00386 M
  FS = 1.50,  FNOP= 1.30

FUEL TANKS (NO.= 1)                           1066.27
 (CYLINDRICAL/SQRT(2) ELLIPTICAL)
  DIAMETER=    4.267 M
  LENGTH  =    3.523 M
  VOLUME  =   35.994 M3
  DOME THK=   .00514 M
  CYL THK =   .00852 M
  FS = 1.50,  FNOP= 1.30

PRESSURANT                                     113.699

PRESSURANT TANKS (NO.= 1)                      610.16
  DIA=   1.7322 M
  VOL=    2.721 M3
  THK=   .01462 M
  FS = 1.50,  FNOP= 1.10

FUEL TANK INSULATION                            93.51
OXIDIZER TANK INSULATION                        43.45

ENGINES (NO.= 1)                                45.36

COMPONENTS AND LINES                           554.74
ENG. MOUNTS,SUPPORTS                          1307.25

TOTAL WET SYSTEM MASS                         22969.0
TOTAL BURNOUT MASS                             4876.0
   (INCL.NON-USABLE PROP. AND GAS)

MASS FRACTION                                    .772
TOTAL IMPULSE                            74251127.2 N-S

             PRESSURE SCHEDULE(N/M2  )   AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =   .2482E+08   INITIAL CHAMBER PRESSURE =0.
INITIAL OX SYS PRESSURE   =   .1069E+07   FINAL OX SYS PRESSURE    =  .1069E+07
INITIAL FU SYS PRESSURE   =   .1138E+07   FINAL FU SYS PRESSURE    =  .1138E+07
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9 BURNS, CONSTANT ACCELERATION, T/M=0.1

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   LH2/LO2  MAX PERF  PRESS FED             MR=5

VEHICLE MASS  =27215.5 KG    DELTA V=  4291.6 M/S   AVE. ISP=4442.2 N-S/KG

TOTAL PROPELLANT                          17671.76 KG
  USABLE FUEL                  2785.94
  USABLE OXIDIZER             13929.71
  FUEL TRAPPED                  101.10
  OXID TRAPPED                  494.70
  FUEL START-S/D LOSSES           6.80
  OXID START-S/D LOSSES           6.80
  FUEL BOILOFF                  151.45
  OXIDIZER BOILOFF              195.24

OXIDIZER TANKS (NO.= 1)                     370.33
 (ELLIPSOIDAL)
  DIAMETER=    3.292 M
  LENGTH  =    2.328 M
  VOLUME  =   13.207 M3
  AVG THK =   .00373 M
  FS = 1.50,  FNOP= 1.30

FUEL TANKS (NO.= 1)                        1317.60
 (CYLINDRICAL/SQRT(2) ELLIPTICAL)
  DIAMETER=    4.267 M
  LENGTH  =    4.134 M
  VOLUME  =   44.742 M3
  DOME THK=   .00514 M
  CYL THK =   .00852 M
  FS = 1.50,  FNOP= 1.30

PRESSURANT                                  137.982

PRESSURANT TANKS (NO.= 1)                   741.35
  DIA=   1.8484 M
  VOL=    3.307 M3
  THK=   .01560 M
  FS = 1.50,  FNOP= 1.10

FUEL TANK INSULATION                        107.92
OXIDIZER TANK INSULATION                     40.47

ENGINES (NO.= 1)                            238.14

COMPONENTS AND LINES                        554.74
ENG. MOUNTS,SUPPORTS                       1301.81

TOTAL WET SYSTEM MASS                      22482.1
TOTAL BURNOUT MASS                          5406.2
   (INCL.NON-USABLE PROP. AND GAS)

MASS FRACTION                                 .744
TOTAL IMPULSE                          74257814.7 N-S

              PRESSURE SCHEDULE(N/M2  )   AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =   .2482E+08   INITIAL CHAMBER PRESSURE =0.
INITIAL OX SYS PRESSURE   =   .1069E+07   FINAL OX SYS PRESSURE    =  .1069E+07
INITIAL FU SYS PRESSURE   =   .1138E+07   FINAL FU SYS PRESSURE    =  .1138E+07
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9 BURNS, CONSTANT ACCELERATION, T/M=0.1

```
   LH2/LO2  MAX PERF  PRESS FED              MR=6

 VEHICLE MASS  =27215.5 KG    DELTA V=  4291.6 M/S   AVE. ISP=4383.4 N-S/KG

 TOTAL PROPELLANT                         17805.40 KG
   USABLE FUEL                  2407.14
   USABLE OXIDIZER             14442.87
   FUEL TRAPPED                   87.40
   OXID TRAPPED                  511.69
   FUEL START-S/D LOSSES           6.80
   OXID START-S/D LOSSES           6.80
   FUEL BOILOFF                  146.26
   OXIDIZER BOILOFF              196.44

 OXIDIZER TANKS (NO.= 1)                    383.79
  (ELLIPSOIDAL)
   DIAMETER=    3.331 M
   LENGTH  =    2.356 M
   VOLUME  =   13.687 M3
   AVG THK =   .00377 M
   FS = 1.50,  FNOP= 1.30

 FUEL TANKS (NO.= 1)                       1149.73
  (CYLINDRICAL/SQRT(2) ELLIPTICAL)
   DIAMETER=    4.267 M
   LENGTH  =    3.726 M
   VOLUME  =   38.899 M3
   DOME THK=   .00514 M
   CYL THK =   .00852 M
   FS = 1.50,  FNOP= 1.30

 PRESSURANT                                 121.419

 PRESSURANT TANKS (NO.= 1)                  651.97
   DIA=    1.7709 M
   VOL=     2.908 M3
   THK=    .01494 M
   FS = 1.50,  FNOP= 1.10

 FUEL TANK INSULATION                        98.30
 OXIDIZER TANK INSULATION                    41.44

 ENGINES (NO.= 1)                           233.60

 COMPONENTS AND LINES                       554.74
 ENG. MOUNTS,SUPPORTS                      1301.81

 TOTAL WET SYSTEM MASS                     22342.2
 TOTAL BURNOUT MASS                         5135.9
    (INCL.NON-USABLE PROP. AND GAS)

 MASS FRACTION                                .754
 TOTAL IMPULSE                         73863206.1 N-S

              PRESSURE SCHEDULE(N/M2  )  AT T=294.4 K

 GAS TANK LOCK-UP PRESSURE =  .2482E+08   INITIAL CHAMBER PRESSURE =0.
 INITIAL OX SYS PRESSURE   =  .1069E+07   FINAL OX SYS PRESSURE   = .1069E+07
 INITIAL FU SYS PRESSURE   =  .1138E+07   FINAL FU SYS PRESSURE   = .1138E+07
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9 BURNS, CONSTANT ACCELERATION, T/M=0.1

LH2/LO2 MAX PERF PRESS FED MR=7

VEHICLE MASS =27215.5 KG DELTA V= 4291.6 M/S AVE. ISP=4285.3 N-S/KG

TOTAL PROPELLANT		18034.39 KG
USABLE FUEL	2134.50	
USABLE OXIDIZER	14941.48	
FUEL TRAPPED	77.31	
OXID TRAPPED	527.40	
FUEL START-S/D LOSSES	6.80	
OXID START-S/D LOSSES	6.80	
FUEL BOILOFF	142.52	
OXIDIZER BOILOFF	197.59	

OXIDIZER TANKS (NO.= 1) 396.84
(ELLIPSOIDAL)
DIAMETER= 3.369 M
LENGTH = 2.382 M
VOLUME = 14.153 M3
AVG THK = .00381 M
FS = 1.50, FNOP= 1.30

FUEL TANKS (NO.= 1) 1028.81
(CYLINDRICAL/SQRT(2) ELLIPTICAL)
DIAMETER= 4.267 M
LENGTH = 3.431 M
VOLUME = 34.690 M3
DOME THK= .00514 M
CYL THK = .00852 M
FS = 1.50, FNOP= 1.30

PRESSURANT 109.585

PRESSURANT TANKS (NO.= 1) 588.09
DIA= 1.7111 M
VOL= 2.623 M3
THK= .01444 M
FS = 1.50, FNOP= 1.10

FUEL TANK INSULATION 91.36
OXIDIZER TANK INSULATION 42.38

ENGINES (NO.= 1) 226.80

COMPONENTS AND LINES 554.74
ENG. MOUNTS,SUPPORTS 1301.81

TOTAL WET SYSTEM MASS 22374.8
TOTAL BURNOUT MASS 4945.1
(INCL.NON-USABLE PROP. AND GAS)

MASS FRACTION .763
TOTAL IMPULSE 73179157.3 N-S

PRESSURE SCHEDULE(N/M2) AT T=294.4 K

GAS TANK LOCK-UP PRESSURE = .2482E+08 INITIAL CHAMBER PRESSURE =0.
INITIAL OX SYS PRESSURE = .1069E+07 FINAL OX SYS PRESSURE = .1069E+07
INITIAL FU SYS PRESSURE = .1138E+07 FINAL FU SYS PRESSURE = .1138E+07

9 BURNS, CONSTANT ACCELERATION, T/M=0.01

LH2/LO2 MIN LENGTH PRESS FED MR=5

VEHICLE MASS =27215.5 KG DELTA V= 4815.8 M/S AVE. ISP=4373.6 N-S/KG

TOTAL PROPELLANT		19111.91 KG
USABLE FUEL	2999.83	
USABLE OXIDIZER	14999.16	
FUEL TRAPPED	119.07	
OXID TRAPPED	582.35	
FUEL START-S/D LOSSES	15.42	
OXID START-S/D LOSSES	15.42	
FUEL BOILOFF	158.08	
OXIDIZER BOILOFF	222.58	

OXIDIZER TANKS (NO.= 1) 520.13
(TOROIDAL)
INNER DIA= 1.411 M
OUTER DIA= 4.267 M
HEIGHT = 1.428 M
VOLUME = 14.285 M3
AVG THK = .00313 M
FS = 1.50, FNOP= 1.50

FUEL TANKS (NO.= 1) 1421.90
(CYLINDRICAL/SQRT(2) ELLIPTICAL)
DIAMETER= 4.267 M
LENGTH = 4.388 M
VOLUME = 48.373 M3
DOME THK= .00514 M
CYL THK = .00852 M
FS = 1.50, FNOP= 1.30

PRESSURANT 148.717

PRESSURANT TANKS (NO.= 1) 798.95
DIA= 1.8951 M
VOL= 3.564 M3
THK= .01599 M
FS = 1.50, FNOP= 1.10

FUEL TANK INSULATION 113.90
OXIDIZER TANK INSULATION 58.61

ENGINES (NO.= 1) 36.29

COMPONENTS AND LINES 589.67
ENG. MOUNTS,SUPPORTS 1305.44

TOTAL WET SYSTEM MASS 24105.5
TOTAL BURNOUT MASS 5695.0
(INCL.NON-USABLE PROP. AND GAS)

MASS FRACTION .747
TOTAL IMPULSE 78723341.6 N-S

PRESSURE SCHEDULE(N/M2) AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =	.2482E+08	INITIAL CHAMBER PRESSURE =	0.
INITIAL OX SYS PRESSURE =	.1069E+07	FINAL OX SYS PRESSURE =	.1069E+07
INITIAL FU SYS PRESSURE =	.1138E+07	FINAL FU SYS PRESSURE =	.1138E+07

9 BURNS, CONSTANT ACCELERATION, T/M=0.01

LH2/LO2 MIN LENGTH PRESS FED MR=6

VEHICLE MASS =27215.5 KG DELTA V= 4815.8 M/S AVE. ISP=4295.1 N-S/KG

TOTAL PROPELLANT		19292.72 KG
USABLE FUEL	2597.15	
USABLE OXIDIZER	15582.91	
FUEL TRAPPED	102.93	
OXID TRAPPED	602.93	
FUEL START-S/D LOSSES	15.42	
OXID START-S/D LOSSES	15.42	
FUEL BOILOFF	152.47	
OXIDIZER BOILOFF	223.48	

OXIDIZER TANKS (NO.= 1) 548.56
(TOROIDAL)
INNER DIA= 1.338 M
OUTER DIA= 4.267 M
HEIGHT = 1.464 M
VOLUME = 14.831 M3
AVG THK = .00326 M
FS = 1.50, FNOP= 1.50

FUEL TANKS (NO.= 1) 1242.75
(CYLINDRICAL/SQRT(2) ELLIPTICAL)
DIAMETER= 4.267 M
LENGTH = 3.952 M
VOLUME = 42.137 M3
DOME THK= .00514 M
CYL THK = .00852 M
FS = 1.50, FNOP= 1.30

PRESSURANT 131.130

PRESSURANT TANKS (NO.= 1) 704.05
DIA= 1.8168 M
VOL= 3.140 M3
THK= .01533 M
FS = 1.50, FNOP= 1.10

FUEL TANK INSULATION 103.63
OXIDIZER TANK INSULATION 59.34

ENGINES (NO.= 1) 34.02

COMPONENTS AND LINES 589.67
ENG. MOUNTS,SUPPORTS 1305.44

TOTAL WET SYSTEM MASS 24011.3
TOTAL BURNOUT MASS 5424.4
(INCL.NON-USABLE PROP. AND GAS)

MASS FRACTION .757
TOTAL IMPULSE 78089037.9 N-S

PRESSURE SCHEDULE(N/M2) AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =	.2482E+08	INITIAL CHAMBER PRESSURE =	0.
INITIAL OX SYS PRESSURE =	.1069E+07	FINAL OX SYS PRESSURE =	.1069E+07
INITIAL FU SYS PRESSURE =	.1138E+07	FINAL FU SYS PRESSURE =	.1138E+07

9 BURNS, CONSTANT ACCELERATION, T/M=0.01

LH2/LO2 MIN LENGTH PRESS FED MR=7

VEHICLE MASS =27215.5 KG DELTA V= 4815.8 M/S AVE. ISP=4177.4 N-S/KG

TOTAL PROPELLANT		19571.36 KG
USABLE FUEL	2306.89	
USABLE OXIDIZER	16148.20	
FUEL TRAPPED	91.02	
OXID TRAPPED	621.68	
FUEL START-S/D LOSSES	15.42	
OXID START-S/D LOSSES	15.42	
FUEL BOILOFF	148.42	
OXIDIZER BOILOFF	224.31	
OXIDIZER TANKS (NO.= 1) (TOROIDAL) INNER DIA= 1.268 M, OUTER DIA= 4.267 M, HEIGHT = 1.500 M, VOLUME = 15.359 M3, AVG THK = .00340 M, FS = 1.50, FNOP= 1.50		577.73
FUEL TANKS (NO.= 1) (CYLINDRICAL/SQRT(2) ELLIPTICAL) DIAMETER= 4.267 M, LENGTH = 3.637 M, VOLUME = 37.638 M3, DOME THK= .00514 M, CYL THK = .00852 M, FS = 1.50, FNOP= 1.30		1113.50
PRESSURANT		118.551
PRESSURANT TANKS (NO.= 1) DIA= 1.7564 M, VOL= 2.837 M3, THK= .01482 M, FS = 1.50, FNOP= 1.10		636.14
FUEL TANK INSULATION		96.22
OXIDIZER TANK INSULATION		60.00
ENGINES (NO.= 1)		31.75
COMPONENTS AND LINES		589.67
ENG. MOUNTS,SUPPORTS		1305.44
TOTAL WET SYSTEM MASS		24100.4
TOTAL BURNOUT MASS (INCL.NON-USABLE PROP. AND GAS)		5241.7
MASS FRACTION		.766
TOTAL IMPULSE		77098534.7 N-S

PRESSURE SCHEDULE(N/M2) AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =	.2482E+08	INITIAL CHAMBER PRESSURE =	0.
INITIAL OX SYS PRESSURE =	.1069E+07	FINAL OX SYS PRESSURE =	.1069E+07
INITIAL FU SYS PRESSURE =	.1138E+07	FINAL FU SYS PRESSURE =	.1138E+07

9 BURNS, CONSTANT ACCELERATION, $T/\dot{m}=0.015$

```
   LH2/LO2  MIN LENGTH  PRESS FED              MR=5

VEHICLE MASS  =27215.5 KG    DELTA V=  4480.6 M/S   AVE. ISP=4383.4 N-S/KG

TOTAL PROPELLANT                             18323.82 KG
  USABLE FUEL                      2877.32
  USABLE OXIDIZER                 14386.58
  FUEL TRAPPED                      114.01
  OXID TRAPPED                      557.80
  FUEL START-S/D LOSSES               7.26
  OXID START-S/D LOSSES               7.26
  FUEL BOILOFF                      154.55
  OXIDIZER BOILOFF                  219.05

OXIDIZER TANKS (NO.= 1)                        491.30
 (TOROIDAL)
  INNER DIA=     1.490 M
  OUTER DIA=     4.267 M
  HEIGHT   =     1.389 M
  VOLUME   =    13.699 M3
  AVG THK  =    .00300 M
  FS = 1.50,  FNOP= 1.50

FUEL TANKS (NO.= 1)                           1363.12
 (CYLINDRICAL/SQRT(2) ELLIPTICAL)
  DIAMETER=     4.267 M
  LENGTH  =     4.245 M
  VOLUME  =    46.327 M3
  DOME THK=    .00514 M
  CYL THK =    .00852 M
  FS = 1.50,  FNOP= 1.30

PRESSURANT                                     142.471

PRESSURANT TANKS (NO.= 1)                      765.40
  DIA=    1.8682 M
  VOL=     3.414 M3
  THK=    .01576 M
  FS = 1.50,  FNOP= 1.10

FUEL TANK INSULATION                           110.53
OXIDIZER TANK INSULATION                        57.79

ENGINES (NO.= 1)                                54.43

COMPONENTS AND LINES                           589.67
ENG. MOUNTS,SUPPORTS                          1293.65

TOTAL WET SYSTEM MASS                         23192.2
TOTAL BURNOUT MASS                             5540.2
   (INCL.NON-USABLE PROP. AND GAS)

MASS FRACTION                                    .744
TOTAL IMPULSE                            75677490.5 N-S

             PRESSURE SCHEDULE(N/M2  )   AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =    .2482E+08    INITIAL CHAMBER PRESSURE =0.
INITIAL OX SYS PRESSURE   =    .1069E+07    FINAL OX SYS PRESSURE    =  .1069E+07
INITIAL FU SYS PRESSURE   =    .1138E+07    FINAL FU SYS PRESSURE    =  .1138E+07
```

9 BURNS, CONSTANT ACCELERATION, T/M=0.015

LH2/LO2 MIN LENGTH PRESS FED MR=6

VEHICLE MASS =27215.5 KG DELTA V= 4480.6 M/S AVE. ISP=4304.9 N-S/KG

TOTAL PROPELLANT		18505.25 KG
USABLE FUEL	2492.18	
USABLE OXIDIZER	14953.09	
FUEL TRAPPED	98.78	
OXID TRAPPED	577.49	
FUEL START-S/D LOSSES	7.26	
OXID START-S/D LOSSES	7.26	
FUEL BOILOFF	149.22	
OXIDIZER BOILOFF	219.98	

OXIDIZER TANKS (NO.= 1) 517.32
(TOROIDAL)
INNER DIA= 1.419 M
OUTER DIA= 4.267 M
HEIGHT = 1.424 M
VOLUME = 14.229 M3
AVG THK = .00312 M
FS = 1.50, FNOP= 1.50

FUEL TANKS (NO.= 1) 1191.87
(CYLINDRICAL/SQRT(2) ELLIPTICAL)
DIAMETER= 4.267 M
LENGTH = 3.828 M
VOLUME = 40.366 M3
DOME THK= .00514 M
CYL THK = .00852 M
FS = 1.50, FNOP= 1.30

PRESSURANT 125.656

PRESSURANT TANKS (NO.= 1) 674.66
DIA= 1.7912 M
VOL= 3.009 M3
THK= .01511 M
FS = 1.50, FNOP= 1.10

FUEL TANK INSULATION	100.71
OXIDIZER TANK INSULATION	58.53
ENGINES (NO.= 1)	49.90
COMPONENTS AND LINES	589.67
ENG. MOUNTS, SUPPORTS	1293.65
TOTAL WET SYSTEM MASS	23107.2
TOTAL BURNOUT MASS (INCL.NON-USABLE PROP. AND GAS)	5278.2
MASS FRACTION	.755
TOTAL IMPULSE	75103960.2 N-S

PRESSURE SCHEDULE(N/M2) AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =	.2482E+08	INITIAL CHAMBER PRESSURE =	0.
INITIAL OX SYS PRESSURE =	.1069E+07	FINAL OX SYS PRESSURE =	.1069E+07
INITIAL FU SYS PRESSURE =	.1138E+07	FINAL FU SYS PRESSURE =	.1138E+07

9 BURNS, CONSTANT ACCELERATION, T/M=0.015

```
    LH2/LO2  MIN LENGTH  PRESS FED             MR=7

VEHICLE MASS  =27215.5 KG    DELTA V=  4480.6 M/S   AVE. ISP=4187.2 N-S/KG

TOTAL PROPELLANT                            18785.32 KG
  USABLE FUEL                     2215.18
  USABLE OXIDIZER                15506.26
  FUEL TRAPPED                      87.67
  OXID TRAPPED                     595.48
  FUEL START-S/D LOSSES              7.26
  OXID START-S/D LOSSES              7.26
  FUEL BOILOFF                     145.38
  OXIDIZER BOILOFF                 220.83

OXIDIZER TANKS (NO.= 1)                       543.99
 (TOROIDAL)
  INNER DIA=     1.350 M
  OUTER DIA=     4.267 M
  HEIGHT   =     1.459 M
  VOLUME   =    14.745 M3
  AVG THK  =    .00324 M
  FS = 1.50,  FNOP= 1.50

FUEL TANKS (NO.= 1)                          1068.64
 (CYLINDRICAL/SQRT(2) ELLIPTICAL)
  DIAMETER=     4.267 M
  LENGTH  =     3.528 M
  VOLUME  =    36.077 M3
  DOME THK=    .00514 M
  CYL THK =    .00852 M
  FS = 1.50,  FNOP= 1.30

PRESSURANT                                    113.660

PRESSURANT TANKS (NO.= 1)                     609.90
  DIA=    1.7320 M
  VOL=     2.720 M3
  THK=    .01461 M
  FS = 1.50,  FNOP= 1.10

FUEL TANK INSULATION                           93.64
OXIDIZER TANK INSULATION                       59.22

ENGINES (NO.= 1)                               45.36

COMPONENTS AND LINES                          589.67
ENG. MOUNTS,SUPPORTS                         1293.65

TOTAL WET SYSTEM MASS                        23203.1
TOTAL BURNOUT MASS                            5100.9
   (INCL.NON-USABLE PROP. AND GAS)

MASS FRACTION                                   .764
TOTAL IMPULSE                           74207444.3 N-S

             PRESSURE SCHEDULE(N/M2  )   AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =   .2482E+08   INITIAL CHAMBER PRESSURE =0.
INITIAL OX SYS PRESSURE   =   .1069E+07   FINAL OX SYS PRESSURE    =  .1069E+07
INITIAL FU SYS PRESSURE   =   .1138E+07   FINAL FU SYS PRESSURE    =  .1138E+07
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9 BURNS, CONSTANT ACCELERATION, T/M=0.1

```
   LH2/LO2  MIN LENGTH  PRESS FED           MR=5

VEHICLE MASS  =27215.5 KG     DELTA V=  4291.6 M/S   AVE. ISP=4442.2 N-S/KG

TOTAL PROPELLANT                         17732.90 KG
  USABLE FUEL                  2784.21
  USABLE OXIDIZER             13921.05
  FUEL TRAPPED                  109.76
  OXID TRAPPED                  536.98
  FUEL START-S/D LOSSES           6.80
  OXID START-S/D LOSSES           6.80
  FUEL BOILOFF                  151.54
  OXIDIZER BOILOFF              215.76

OXIDIZER TANKS (NO.= 1)                    470.50
 (TOROIDAL)
  INNER DIA=     1.549 M
  OUTER DIA=     4.267 M
  HEIGHT   =     1.359 M
  VOLUME   =    13.256 M3
  AVG THK  =    .00290 M
  FS = 1.50,  FNOP= 1.50

FUEL TANKS (NO.= 1)                       1320.56
 (CYLINDRICAL/SQRT(2) ELLIPTICAL)
  DIAMETER=     4.267 M
  LENGTH  =     4.141 M
  VOLUME  =    44.845 M3
  DOME THK=    .00514 M
  CYL THK =    .00852 M
  FS = 1.50,  FNOP= 1.30

PRESSURANT                                 137.927

PRESSURANT TANKS (NO.= 1)                  741.00
  DIA=    1.8481 M
  VOL=     3.305 M3
  THK=    .01559 M
  FS = 1.50,  FNOP= 1.10

FUEL TANK INSULATION                       108.09
OXIDIZER TANK INSULATION                    57.14

ENGINES (NO.= 1)                           238.14

COMPONENTS AND LINES                       589.67
ENG. MOUNTS,SUPPORTS                      1284.12

TOTAL WET SYSTEM MASS                     22680.0
TOTAL BURNOUT MASS                         5593.9
   (INCL.NON-USABLE PROP. AND GAS)

MASS FRACTION                                .737
TOTAL IMPULSE                         74211602.7 N-S

             PRESSURE SCHEDULE(N/M2  )   AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =   .2482E+08   INITIAL CHAMBER PRESSURE =0.
INITIAL OX SYS PRESSURE   =   .1069E+07   FINAL OX SYS PRESSURE   =  .1069E+07
INITIAL FU SYS PRESSURE   =   .1138E+07   FINAL FU SYS PRESSURE   =  .1138E+07
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9 BURNS, CONSTANT ACCELERATION, T/M=0.1

```
   LH2/LO2  MIN LENGTH  PRESS FED            MR=6

VEHICLE MASS   =27215.5 KG    DELTA V=  4291.6 M/S   AVE. ISP=4383.4 N-S/KG

TOTAL PROPELLANT                          17865.83 KG
  USABLE FUEL                    2405.67
  USABLE OXIDIZER               14434.03
  FUEL TRAPPED                     94.69
  OXID TRAPPED                    554.87
  FUEL START-S/D LOSSES             6.80
  OXID START-S/D LOSSES             6.80
  FUEL BOILOFF                    146.33
  OXIDIZER BOILOFF                216.62

OXIDIZER TANKS (NO.= 1)                     493.10
 (TOROIDAL)
  INNER DIA=     1.485 M
  OUTER DIA=     4.267 M
  HEIGHT   =     1.391 M
  VOLUME   =    13.736 M3
  AVG THK  =    .00301 M
  FS = 1.50,  FNOP= 1.50

FUEL TANKS (NO.= 1)                        1152.22
 (CYLINDRICAL/SQRT(2) ELLIPTICAL)
  DIAMETER=     4.267 M
  LENGTH  =     3.732 M
  VOLUME  =    38.986 M3
  DOME THK=    .00514 M
  CYL THK =    .00852 M
  FS = 1.50,  FNOP= 1.30

PRESSURANT                                  121.374

PRESSURANT TANKS (NO.= 1)                   651.67
  DIA=    1.7706 M
  VOL=     2.907 M3
  THK=    .01494 M
  FS = 1.50,  FNOP= 1.10

FUEL TANK INSULATION                         98.44
OXIDIZER TANK INSULATION                     57.84

ENGINES (NO.= 1)                            233.60

COMPONENTS AND LINES                        589.67
ENG. MOUNTS,SUPPORTS                       1284.12

TOTAL WET SYSTEM MASS                      22547.9
TOTAL BURNOUT MASS                          5331.6
   (INCL.NON-USABLE PROP. AND GAS)

MASS FRACTION                                 .747
TOTAL IMPULSE                          73818020.7 N-S

            PRESSURE SCHEDULE(N/M2  )   AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =   .2482E+08   INITIAL CHAMBER PRESSURE =0.
INITIAL OX SYS PRESSURE   =   .1069E+07   FINAL OX SYS PRESSURE    =  .1069E+07
INITIAL FU SYS PRESSURE   =   .1138E+07   FINAL FU SYS PRESSURE    =  .1138E+07
```

9 BURNS, CONSTANT ACCELERATION, T/M=0.1

LH2/LO2 MIN LENGTH PRESS FED MR=7

VEHICLE MASS =27215.5 KG DELTA V= 4291.6 M/S AVE. ISP=4285.3 N-S/KG

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TOTAL PROPELLANT                                 18092.69 KG
  USABLE FUEL                       2133.21
  USABLE OXIDIZER                  14932.50
  FUEL TRAPPED                        83.69
  OXID TRAPPED                       569.67
  FUEL START-S/D LOSSES                6.80
  OXID START-S/D LOSSES                6.80
  FUEL BOILOFF                       142.58
  OXIDIZER BOILOFF                   217.42

OXIDIZER TANKS (NO.= 1)                            515.89
 (TOROIDAL)
  INNER DIA=     1.423 M
  OUTER DIA=     4.267 M
  HEIGHT   =     1.422 M
  VOLUME   =    14.201 M3
  AVG THK  =    .00311 M
  FS = 1.50,  FNOP= 1.50

FUEL TANKS (NO.= 1)                               1030.99
 (CYLINDRICAL/SQRT(2) ELLIPTICAL)
  DIAMETER=     4.267 M
  LENGTH   =    3.437 M
  VOLUME   =   34.766 M3
  DOME THK=    .00514 M
  CYL THK =    .00852 M
  FS = 1.50,  FNOP= 1.30

PRESSURANT                                         109.547

PRESSURANT TANKS (NO.= 1)                          587.83
  DIA=    1.7108 M
  VOL=     2.622 M3
  THK=    .01443 M
  FS = 1.50,  FNOP= 1.10

FUEL TANK INSULATION                                91.49
OXIDIZER TANK INSULATION                            58.50

ENGINES (NO.= 1)                                   226.80

COMPONENTS AND LINES                               589.67
ENG. MOUNTS,SUPPORTS                              1284.12

TOTAL WET SYSTEM MASS                             22587.5
TOTAL BURNOUT MASS                                 5148.2
   (INCL.NON-USABLE PROP. AND GAS)

MASS FRACTION                                        .756
TOTAL IMPULSE                                 73135184.6 N-S

             PRESSURE SCHEDULE(N/M2  )  AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =  .2482E+08   INITIAL CHAMBER PRESSURE =0.
INITIAL OX SYS PRESSURE   =  .1069E+07   FINAL OX SYS PRESSURE    =  .1069E+07
INITIAL FU SYS PRESSURE   =  .1138E+07   FINAL FU SYS PRESSURE    =  .1138E+07
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9 BURNS, CONSTANT ACCELERATION, T/M=0.01

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   LH2/LO2  MAX PERF  PUMP FED                MR=5

VEHICLE MASS  =27215.5 KG    DELTA V=  4815.8 M/S   AVE. ISP=4442.2 N-S/KG

TOTAL PROPELLANT                          18908.60 KG
  USABLE FUEL                    2976.03
  USABLE OXIDIZER               14880.13
  FUEL TRAPPED                    112.47
  OXID TRAPPED                    549.17
  FUEL START-S/D LOSSES            15.42
  OXID START-S/D LOSSES            15.42
  FUEL BOILOFF                    157.67
  OXIDIZER BOILOFF                202.29

OXIDIZER TANKS (NO.= 1)                       76.19
 (ELLIPSOIDAL)
  DIAMETER=     3.367 M
  LENGTH   =    2.381 M
  VOLUME   =   14.129 M3
  AVG THK  =   .00064 M
  FS = 1.50,  FNOP= 1.50

FUEL TANKS (NO.= 1)                          216.75
 (CYLINDRICAL/SQRT(2) ELLIPTICAL)
  DIAMETER=     4.267 M
  LENGTH   =    4.356 M
  VOLUME   =   47.920 M3
  DOME THK=    .00069 M
  CYL THK  =   .00114 M
  FS = 1.50,  FNOP= 1.50

PRESSURANT                                    18.947

PRESSURANT TANKS (NO.= 1)                    101.65
  DIA=     .9531 M
  VOL=      .453 M3
  THK=    .00804 M
  FS = 1.50,  FNOP= 1.10

FUEL TANK INSULATION                         113.16
OXIDIZER TANK INSULATION                      42.33

ENGINES (NO.= 1)                              37.19

COMPONENTS AND LINES                         554.29
ENG. MOUNTS,SUPPORTS                        1322.22

TOTAL WET SYSTEM MASS                        21391.3
TOTAL BURNOUT MASS                            3144.4
   (INCL.NON-USABLE PROP. AND GAS)

MASS FRACTION                                   .835
TOTAL IMPULSE                          79324355.6 N-S

             PRESSURE SCHEDULE(N/M2  )   AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =   .2482E+08    INITIAL CHAMBER PRESSURE =0.
INITIAL OX SYS PRESSURE   =   .1517E+06    FINAL OX SYS PRESSURE    =  .1517E+06
INITIAL FU SYS PRESSURE   =   .1517E+06    FINAL FU SYS PRESSURE    =  .1517E+06
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9 BURNS, CONSTANT ACCELERATION, T/M=0.01

```
    LH2/LO2  MAX PERF  PUMP FED              MR=6

VEHICLE MASS  =27215.5 KG    DELTA V=  4815.8 M/S   AVE. ISP=4373.6 N-S/KG

TOTAL PROPELLANT                          19064.40 KG
  USABLE FUEL                  2573.20
  USABLE OXIDIZER             15439.22
  FUEL TRAPPED                   97.25
  OXID TRAPPED                  568.23
  FUEL START-S/D LOSSES          15.42
  OXID START-S/D LOSSES          15.42
  FUEL BOILOFF                  152.07
  OXIDIZER BOILOFF              203.58

OXIDIZER TANKS (NO.= 1)                      78.06
 (ELLIPSOIDAL)
  DIAMETER=    3.408 M
  LENGTH  =    2.410 M
  VOLUME  =   14.652 M3
  AVG THK =   .00064 M
  FS = 1.50,  FNOP= 1.50

FUEL TANKS (NO.= 1)                         189.24
 (CYLINDRICAL/SQRT(2) ELLIPTICAL)
  DIAMETER=    4.267 M
  LENGTH  =    3.921 M
  VOLUME  =   41.696 M3
  DOME THK=   .00069 M
  CYL THK =   .00114 M
  FS = 1.50,  FNOP= 1.50

PRESSURANT                                  16.696

PRESSURANT TANKS (NO.= 1)                    89.51
  DIA=     .9136 M
  VOL=      .399 M3
  THK=    .00771 M
  FS = 1.50,  FNOP= 1.10

FUEL TANK INSULATION                        102.90
OXIDIZER TANK INSULATION                     43.37

ENGINES (NO.= 1)                             36.29

COMPONENTS AND LINES                        554.29
ENG. MOUNTS,SUPPORTS                       1322.22

TOTAL WET SYSTEM MASS                      21497.0
TOTAL BURNOUT MASS                          3098.1
   (INCL.NON-USABLE PROP. AND GAS)

MASS FRACTION                                 .838
TOTAL IMPULSE                          78782087.3 N-S

             PRESSURE SCHEDULE(N/M2  )   AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =    .2482E+08    INITIAL CHAMBER PRESSURE =0.
INITIAL OX SYS PRESSURE   =    .1517E+06    FINAL OX SYS PRESSURE    =  .1517E+06
INITIAL FU SYS PRESSURE   =    .1517E+06    FINAL FU SYS PRESSURE    =  .1517E+06
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9 BURNS, CONSTANT ACCELERATION, T/M=0.01

```
   LH2/LO2  MAX PERF  PUMP FED               MR=7

VEHICLE MASS  =27215.5 KG    DELTA V=  4815.8 M/S   AVE. ISP=4285.3 N-S/KG

TOTAL PROPELLANT                             19269.25 KG
  USABLE FUEL                     2276.90
  USABLE OXIDIZER                15938.33
  FUEL TRAPPED                      86.10
  OXID TRAPPED                     584.41
  FUEL START-S/D LOSSES             15.42
  OXID START-S/D LOSSES             15.42
  FUEL BOILOFF                     147.95
  OXIDIZER BOILOFF                 204.72

OXIDIZER TANKS (NO.= 1)                         79.70
 (ELLIPSOIDAL)
  DIAMETER=    3.444 M
  LENGTH  =    2.435 M
  VOLUME  =   15.118 M3
  AVG THK =   .00064 M
  FS = 1.50,  FNOP= 1.50

FUEL TANKS (NO.= 1)                            169.01
 (CYLINDRICAL/SQRT(2) ELLIPTICAL)
  DIAMETER=    4.267 M
  LENGTH  =    3.601 M
  VOLUME  =   37.118 M3
  DOME THK=   .00069 M
  CYL THK =   .00114 M
  FS = 1.50,  FNOP= 1.50

PRESSURANT                                     15.049

PRESSURANT TANKS (NO.= 1)                       80.63
  DIA=     .8823 M
  VOL=      .360 M3
  THK=    .00744 M
  FS = 1.50,  FNOP= 1.10

FUEL TANK INSULATION                            95.36
OXIDIZER TANK INSULATION                        44.28

ENGINES (NO.= 1)                                35.38

COMPONENTS AND LINES                           554.29
ENG. MOUNTS,SUPPORTS                          1322.22

TOTAL WET SYSTEM MASS                         21665.2
TOTAL BURNOUT MASS                             3066.4
   (INCL.NON-USABLE PROP. AND GAS)

MASS FRACTION                                    .841
TOTAL IMPULSE                             78061442.1 N-S

             PRESSURE SCHEDULE(N/M2  )   AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =   .2482E+08   INITIAL CHAMBER PRESSURE =0.
INITIAL OX SYS PRESSURE   =   .1517E+06   FINAL OX SYS PRESSURE    =  .1517E+06
INITIAL FU SYS PRESSURE   =   .1517E+06   FINAL FU SYS PRESSURE    =  .1517E+06
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9 BURNS, CONSTANT ACCELERATION, T/M=0.015

```
   LH2/LO2  MAX PERF  PUMP FED              MR=5

VEHICLE MASS  =27215.5 KG    DELTA V=  4480.6 M/S   AVE. ISP=4471.6 N-S/KG

TOTAL PROPELLANT                          18057.04 KG
  USABLE FUEL                    2846.17
  USABLE OXIDIZER               14230.87
  FUEL TRAPPED                    104.04
  OXID TRAPPED                    509.11
  FUEL START-S/D LOSSES             7.26
  OXID START-S/D LOSSES             7.26
  FUEL BOILOFF                    154.00
  OXIDIZER BOILOFF                198.33

OXIDIZER TANKS (NO.= 1)                      73.89
 (ELLIPSOIDAL)
  DIAMETER=    3.316 M
  LENGTH  =    2.345 M
  VOLUME  =   13.495 M3
  AVG THK =   .00064 M
  FS = 1.50,  FNOP= 1.50

FUEL TANKS (NO.= 1)                         207.00
 (CYLINDRICAL/SQRT(2) ELLIPTICAL)
  DIAMETER=    4.267 M
  LENGTH  =    4.202 M
  VOLUME  =   45.714 M3
  DOME THK=   .00069 M
  CYL THK =   .00114 M
  FS = 1.50,  FNOP= 1.50

PRESSURANT                                   18.096

PRESSURANT TANKS (NO.= 1)                    97.09
  DIA=    .9387 M
  VOL=     .433 M3
  THK=   .00792 M
  FS = 1.50,  FNOP= 1.10

FUEL TANK INSULATION                        109.52
OXIDIZER TANK INSULATION                     41.06

ENGINES (NO.= 1)                             41.73

COMPONENTS AND LINES                        554.29
ENG. MOUNTS,SUPPORTS                       1307.25

TOTAL WET SYSTEM MASS                      20507.0
TOTAL BURNOUT MASS                          3063.1
   (INCL.NON-USABLE PROP. AND GAS)

MASS FRACTION                                 .833
TOTAL IMPULSE                          76365658.0 N-S

           PRESSURE SCHEDULE(N/M2  )   AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =   .2482E+08   INITIAL CHAMBER PRESSURE =0.
INITIAL OX SYS PRESSURE   =   .1517E+06   FINAL OX SYS PRESSURE    =  .1517E+06
INITIAL FU SYS PRESSURE   =   .1517E+06   FINAL FU SYS PRESSURE    =  .1517E+06
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9 BURNS, CONSTANT ACCELERATION, T/M=0.015

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   LH2/LO2  MAX PERF  PUMP FED                   MR=6

VEHICLE MASS  =27215.5 KG    DELTA V=  4480.6 M/S   AVE. ISP=4432.4 N-S/KG

TOTAL PROPELLANT                           18144.12 KG
  USABLE FUEL                     2452.39
  USABLE OXIDIZER                14714.34
  FUEL TRAPPED                      89.49
  OXID TRAPPED                     525.36
  FUEL START-S/D LOSSES              7.26
  OXID START-S/D LOSSES              7.26
  FUEL BOILOFF                     148.56
  OXIDIZER BOILOFF                 199.46

OXIDIZER TANKS (NO.= 1)                       75.53
 (ELLIPSOIDAL)
  DIAMETER=     3.352 M
  LENGTH  =     2.370 M
  VOLUME  =    13.948 M3
  AVG THK =    .00064 M
  FS = 1.50,  FNOP= 1.50

FUEL TANKS (NO.= 1)                          180.14
 (CYLINDRICAL/SQRT(2) ELLIPTICAL)
  DIAMETER=     4.267 M
  LENGTH  =     3.777 M
  VOLUME  =    39.635 M3
  DOME THK=    .00069 M
  CYL THK =    .00114 M
  FS = 1.50,  FNOP= 1.50

PRESSURANT                                    15.891

PRESSURANT TANKS (NO.= 1)                     85.20
  DIA=     .8987 M
  VOL=       .380 M3
  THK=    .00758 M
  FS = 1.50,  FNOP= 1.10

FUEL TANK INSULATION                          99.51
OXIDIZER TANK INSULATION                      41.97

ENGINES (NO.= 1)                              40.82

COMPONENTS AND LINES                         554.29
ENG. MOUNTS,SUPPORTS                        1307.25

TOTAL WET SYSTEM MASS                       20544.7
TOTAL BURNOUT MASS                           3015.5
   (INCL.NON-USABLE PROP. AND GAS)

MASS FRACTION                                  .836
TOTAL IMPULSE                           76093308.2 N-S

             PRESSURE SCHEDULE(N/M2  )   AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =   .2482E+08    INITIAL CHAMBER PRESSURE =0.
INITIAL OX SYS PRESSURE   =   .1517E+06    FINAL OX SYS PRESSURE    =  .1517E+06
INITIAL FU SYS PRESSURE   =   .1517E+06    FINAL FU SYS PRESSURE    =  .1517E+06
```

9 BURNS, CONSTANT ACCELERATION, T/M=0.015

```
   LH2/LO2  MAX PERF  PUMP FED                   MR=7

VEHICLE MASS  =27215.5 KG    DELTA V=  4480.6 M/S   AVE. ISP=4344.1 N-S/KG

TOTAL PROPELLANT                           18347.88 KG
  USABLE FUEL                  2170.98
  USABLE OXIDIZER             15196.83
  FUEL TRAPPED                   79.64
  OXID TRAPPED                  540.66
  FUEL START-S/D LOSSES           7.26
  OXID START-S/D LOSSES           7.26
  FUEL BOILOFF                  144.69
  OXIDIZER BOILOFF              200.57

OXIDIZER TANKS (NO.= 1)                      77.15
 (ELLIPSOIDAL)
  DIAMETER=     3.388 M
  LENGTH   =    2.396 M
  VOLUME   =   14.398 M3
  AVG THK  =   .00064 M
  FS = 1.50,   FNOP= 1.50

FUEL TANKS (NO.= 1)                         160.97
 (CYLINDRICAL/SQRT(2) ELLIPTICAL)
  DIAMETER=     4.267 M
  LENGTH   =    3.474 M
  VOLUME   =   35.299 M3
  DOME THK=    .00069 M
  CYL THK  =   .00114 M
  FS = 1.50,   FNOP= 1.50

PRESSURANT                                   14.327

PRESSURANT TANKS (NO.= 1)                    76.76
  DIA=     .8680 M
  VOL=      .342 M3
  THK=    .00732 M
  FS = 1.50,   FNOP= 1.10

FUEL TANK INSULATION                         92.36
OXIDIZER TANK INSULATION                     42.87

ENGINES (NO.= 1)                             39.01

COMPONENTS AND LINES                        554.29
ENG. MOUNTS,SUPPORTS                       1307.25

TOTAL WET SYSTEM MASS                      20712.9
TOTAL BURNOUT MASS                          2985.3
   (INCL.NON-USABLE PROP. AND GAS)

MASS FRACTION                                 .839
TOTAL IMPULSE                          75451734.3 N-S

              PRESSURE SCHEDULE(N/M2  )   AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =   .2482E+08    INITIAL CHAMBER PRESSURE =0.
INITIAL OX SYS PRESSURE   =   .1517E+06    FINAL OX SYS PRESSURE    =  .1517E+06
INITIAL FU SYS PRESSURE   =   .1517E+06    FINAL FU SYS PRESSURE    =  .1517E+06
```

9 BURNS, CONSTANT ACCELERATION, T/M=0.05

LH2/LO2 MAX PERF PUMP FED MR=6

VEHICLE MASS =27215.5 KG DELTA V= 4303.8 M/S AVE. ISP=4491.2 N-S/KG

TOTAL PROPELLANT		17612.48 KG
USABLE FUEL	2376.75	
USABLE OXIDIZER	14260.52	
FUEL TRAPPED	89.80	
OXID TRAPPED	524.90	
FUEL START-S/D LOSSES	7.26	
OXID START-S/D LOSSES	7.26	
FUEL BOILOFF	147.56	
OXIDIZER BOILOFF	198.43	
OXIDIZER TANKS (NO.= 1)		74.04
(ELLIPSOIDAL)		
DIAMETER= 3.319 M		
LENGTH = 2.347 M		
VOLUME = 13.537 M3		
AVG THK = .00064 M		
FS = 1.50, FNOP= 1.50		
FUEL TANKS (NO.= 1)		175.18
(CYLINDRICAL/SQRT(2) ELLIPTICAL)		
DIAMETER= 4.267 M		
LENGTH = 3.699 M		
VOLUME = 38.514 M3		
DOME THK= .00069 M		
CYL THK = .00114 M		
FS = 1.50, FNOP= 1.50		
PRESSURANT		15.423
PRESSURANT TANKS (NO.= 1)		82.68
DIA= .8897 M		
VOL= .369 M3		
THK= .00751 M		
FS = 1.50, FNOP= 1.10		
FUEL TANK INSULATION		97.66
OXIDIZER TANK INSULATION		41.14
ENGINES (NO.= 1)		64.41
COMPONENTS AND LINES		554.29
ENG. MOUNTS,SUPPORTS		1303.62
TOTAL WET SYSTEM MASS		20020.9
TOTAL BURNOUT MASS		3023.1
(INCL.NON-USABLE PROP. AND GAS)		
MASS FRACTION		.831
TOTAL IMPULSE		74725372.2 N-S

PRESSURE SCHEDULE(N/M2) AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =	.2482E+08	INITIAL CHAMBER PRESSURE =	0.
INITIAL OX SYS PRESSURE =	.1517E+06	FINAL OX SYS PRESSURE =	.1517E+06
INITIAL FU SYS PRESSURE =	.1517E+06	FINAL FU SYS PRESSURE =	.1517E+06

9 BURNS, CONSTANT ACCELERATION, T/M=0.1

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   LH2/LO2  MAX PERF  PUMP FED             MR=5

VEHICLE MASS  =27215.5 KG   DELTA V=  4291.6 M/S   AVE. ISP=4579.5 N-S/KG

TOTAL PROPELLANT                         17361.72 KG
  USABLE FUEL                   2735.75
  USABLE OXIDIZER              13678.75
  FUEL TRAPPED                    99.79
  OXID TRAPPED                   488.40
  FUEL START-S/D LOSSES            6.80
  OXID START-S/D LOSSES            6.80
  FUEL BOILOFF                   150.77
  OXIDIZER BOILOFF               194.65

OXIDIZER TANKS (NO.= 1)                     71.98
 (ELLIPSOIDAL)
  DIAMETER=    3.272 M
  LENGTH  =    2.314 M
  VOLUME  =   12.974 M3
  AVG THK =   .00064 M
  FS = 1.50,  FNOP= 1.50

FUEL TANKS (NO.= 1)                        199.32
 (CYLINDRICAL/SQRT(2) ELLIPTICAL)
  DIAMETER=    4.267 M
  LENGTH  =    4.081 M
  VOLUME  =   43.976 M3
  DOME THK=   .00069 M
  CYL THK =   .00114 M
  FS = 1.50,  FNOP= 1.50

PRESSURANT                                  17.408

PRESSURANT TANKS (NO.= 1)                   93.40
  DIA=     .9266 M
  VOL=      .417 M3
  THK=    .00782 M
  FS = 1.50,  FNOP= 1.10

FUEL TANK INSULATION                       106.66
OXIDIZER TANK INSULATION                    39.99

ENGINES (NO.= 1)                            99.79

COMPONENTS AND LINES                       554.29
ENG. MOUNTS,SUPPORTS                      1302.26

TOTAL WET SYSTEM MASS                     19846.8
TOTAL BURNOUT MASS                         3073.3
   (INCL.NON-USABLE PROP. AND GAS)

MASS FRACTION                                .827
TOTAL IMPULSE                          75173527.9 N-S

             PRESSURE SCHEDULE(N/M2  )   AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =   .2482E+08    INITIAL CHAMBER PRESSURE =0.
INITIAL OX SYS PRESSURE   =   .1517E+06    FINAL OX SYS PRESSURE    =  .1517E+06
INITIAL FU SYS PRESSURE   =   .1517E+06    FINAL FU SYS PRESSURE    =  .1517E+06
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9 BURNS, CONSTANT ACCELERATION, T/M=0.1

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   LH2/LO2  MAX PERF  PUMP FED              MR=6

VEHICLE MASS  =27215.5 KG    DELTA V=  4291.6 M/S   AVE. ISP=4559.9 N-S/KG

TOTAL PROPELLANT                         17403.12 KG
  USABLE FUEL                    2351.31
  USABLE OXIDIZER               14107.83
  FUEL TRAPPED                     85.94
  OXID TRAPPED                    503.27
  FUEL START-S/D LOSSES             6.80
  OXID START-S/D LOSSES             6.80
  FUEL BOILOFF                    145.50
  OXIDIZER BOILOFF                195.67

OXIDIZER TANKS (NO.= 1)                     73.46
 (ELLIPSOIDAL)
  DIAMETER=     3.306 M
  LENGTH  =     2.338 M
  VOLUME  =    13.376 M3
  AVG THK =    .00064 M
  FS = 1.50,  FNOP= 1.50

FUEL TANKS (NO.= 1)                        173.11
 (CYLINDRICAL/SQRT(2) ELLIPTICAL)
  DIAMETER=     4.267 M
  LENGTH  =     3.666 M
  VOLUME  =    38.046 M3
  DOME THK=    .00069 M
  CYL THK =    .00114 M
  FS = 1.50,  FNOP= 1.50

PRESSURANT                                  15.252

PRESSURANT TANKS (NO.= 1)                   81.77
  DIA=     .8865 M
  VOL=      .365 M3
  THK=    .00748 M
  FS = 1.50,  FNOP= 1.10

FUEL TANK INSULATION                        96.89
OXIDIZER TANK INSULATION                    40.81

ENGINES (NO.= 1)                            96.16

COMPONENTS AND LINES                       554.29
ENG. MOUNTS,SUPPORTS                      1302.26

TOTAL WET SYSTEM MASS                     19837.1
TOTAL BURNOUT MASS                         3023.2
   (INCL.NON-USABLE PROP. AND GAS)

MASS FRACTION                                .830
TOTAL IMPULSE                          75055167.5 N-S

             PRESSURE SCHEDULE(N/M2  )   AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =  .2482E+08   INITIAL CHAMBER PRESSURE =0.
INITIAL OX SYS PRESSURE   =  .1517E+06   FINAL OX SYS PRESSURE    =  .1517E+06
INITIAL FU SYS PRESSURE   =  .1517E+06   FINAL FU SYS PRESSURE    =  .1517E+06
```

9 BURNS, CONSTANT ACCELERATION, T/M=0.1

LH2/LO2 MAX PERF PUMP FED MR=7

VEHICLE MASS =27215.5 KG DELTA V= 4291.6 M/S AVE. ISP=4510.9 N-S/KG

TOTAL PROPELLANT		17511.50 KG
USABLE FUEL	2070.97	
USABLE OXIDIZER	14496.82	
FUEL TRAPPED	75.64	
OXID TRAPPED	516.23	
FUEL START-S/D LOSSES	6.80	
OXID START-S/D LOSSES	6.80	
FUEL BOILOFF	141.65	
OXIDIZER BOILOFF	196.57	
OXIDIZER TANKS (NO.= 1)		74.78
(ELLIPSOIDAL)		
DIAMETER= 3.336 M		
LENGTH = 2.359 M		
VOLUME = 13.740 M3		
AVG THK = .00064 M		
FS = 1.50, FNOP= 1.50		
FUEL TANKS (NO.= 1)		153.99
(CYLINDRICAL/SQRT(2) ELLIPTICAL)		
DIAMETER= 4.267 M		
LENGTH = 3.364 M		
VOLUME = 33.720 M3		
DOME THK= .00069 M		
CYL THK = .00114 M		
FS = 1.50, FNOP= 1.50		
PRESSURANT		13.687
PRESSURANT TANKS (NO.= 1)		73.33
DIA= .8548 M		
VOL= .327 M3		
THK= .00721 M		
FS = 1.50, FNOP= 1.10		
FUEL TANK INSULATION		89.76
OXIDIZER TANK INSULATION		41.55
ENGINES (NO.= 1)		93.44
COMPONENTS AND LINES		554.29
ENG. MOUNTS,SUPPORTS		1302.26
TOTAL WET SYSTEM MASS		19908.6
TOTAL BURNOUT MASS		2989.0
(INCL.NON-USABLE PROP. AND GAS)		
MASS FRACTION		.832
TOTAL IMPULSE		74738265.9 N-S

PRESSURE SCHEDULE(N/M2) AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =	.2482E+08	INITIAL CHAMBER PRESSURE =	0.
INITIAL OX SYS PRESSURE =	.1517E+06	FINAL OX SYS PRESSURE =	.1517E+06
INITIAL FU SYS PRESSURE =	.1517E+06	FINAL FU SYS PRESSURE =	.1517E+06

9 BURNS, CONSTANT ACCELERATION, T/M=0.01

```
   LH2/LO2  MIN LENGTH  PUMP FED             MR=5

VEHICLE MASS  =27215.5 KG    DELTA V=  4815.8 M/S   AVE. ISP=4442.2 N-S/KG

TOTAL PROPELLANT                          18953.91 KG
  USABLE FUEL                  2974.24
  USABLE OXIDIZER             14871.19
  FUEL TRAPPED                  118.40
  OXID TRAPPED                  579.14
  FUEL START-S/D LOSSES          15.42
  OXID START-S/D LOSSES          15.42
  FUEL BOILOFF                  157.73
  OXIDIZER BOILOFF              222.37

OXIDIZER TANKS (NO.= 1)                     105.21
 (TOROIDAL)
  INNER DIA=     1.427 M
  OUTER DIA=     4.267 M
  HEIGHT   =     1.420 M
  VOLUME   =    14.166 M3
  AVG THK  =    .00064 M
  FS = 1.50,   FNOP= 1.50

FUEL TANKS (NO.= 1)                         188.09
 (CYLINDRICAL/SQRT(2) ELLIPTICAL)
  DIAMETER=     4.267 M
  LENGTH   =    4.361 M
  VOLUME   =   47.982 M3
  DOME THK=    .00069 M
  CYL THK =    .00114 M
  FS = 1.50,   FNOP= 1.30

PRESSURANT                                  18.939

PRESSURANT TANKS (NO.= 1)                   101.60
  DIA=     .9530 M
  VOL=      .453 M3
  THK=    .00804 M
  FS = 1.50,   FNOP= 1.10

FUEL TANK INSULATION                        113.26
OXIDIZER TANK INSULATION                     58.45

ENGINES (NO.= 1)                             37.19

COMPONENTS AND LINES                        589.67
ENG. MOUNTS,SUPPORTS                       1305.44

TOTAL WET SYSTEM MASS                      21471.8
TOTAL BURNOUT MASS                          3215.4
   (INCL.NON-USABLE PROP. AND GAS)

MASS FRACTION                                 .831
TOTAL IMPULSE                          79276703.6 N-S

             PRESSURE SCHEDULE(N/M2  )   AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =   .2482E+08    INITIAL CHAMBER PRESSURE =0.
INITIAL OX SYS PRESSURE   =   .1517E+06    FINAL OX SYS PRESSURE    =  .1517E+06
INITIAL FU SYS PRESSURE   =   .1517E+06    FINAL FU SYS PRESSURE    =  :1517E+06
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9 BURNS, CONSTANT ACCELERATION, T/M=0.01

```
   LH2/LO2  MIN LENGTH  PUMP FED              MR=6

VEHICLE MASS  =27215.5 KG    DELTA V=  4815.8 M/S   AVE. ISP=4373.6 N-S/KG

TOTAL PROPELLANT                          19109.41 KG
  USABLE FUEL                     2571.69
  USABLE OXIDIZER                15430.14
  FUEL TRAPPED                     102.26
  OXID TRAPPED                     599.10
  FUEL START-S/D LOSSES             15.42
  OXID START-S/D LOSSES             15.42
  FUEL BOILOFF                     152.12
  OXIDIZER BOILOFF                 223.25

OXIDIZER TANKS (NO.= 1)                     106.47
 (TOROIDAL)
  INNER DIA=     1.357 M
  OUTER DIA=     4.267 M
  HEIGHT   =     1.455 M
  VOLUME   =    14.689 M3
  AVG THK  =    .00064 M
  FS = 1.50,  FNOP= 1.50

FUEL TANKS (NO.= 1)                         164.21
 (CYLINDRICAL/SQRT(2) ELLIPTICAL)
  DIAMETER=     4.267 M
  LENGTH  =     3.925 M
  VOLUME  =    41.748 M3
  DOME THK=    .00069 M
  CYL THK =    .00114 M
  FS = 1.50,  FNOP= 1.30

PRESSURANT                                  16.690

PRESSURANT TANKS (NO.= 1)                    89.47
  DIA=     .9134 M
  VOL=      .399 M3
  THK=    .00771 M
  FS = 1.50,  FNOP= 1.10

FUEL TANK INSULATION                        102.99
OXIDIZER TANK INSULATION                     59.15

ENGINES (NO.= 1)                             36.29

COMPONENTS AND LINES                        589.67
ENG. MOUNTS,SUPPORTS                       1305.44

TOTAL WET SYSTEM MASS                      21579.8
TOTAL BURNOUT MASS                          3171.7
   (INCL.NON-USABLE PROP. AND GAS)

MASS FRACTION                                 .834
TOTAL IMPULSE                         78735768.6 N-S

             PRESSURE SCHEDULE(N/M2   )   AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =   .2482E+08   INITIAL CHAMBER PRESSURE =0.
INITIAL OX SYS PRESSURE   =   .1517E+06   FINAL OX SYS PRESSURE    =  .1517E+06
INITIAL FU SYS PRESSURE   =   .1517E+06   FINAL FU SYS PRESSURE    =  .1517E+06
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9 BURNS, CONSTANT ACCELERATION, T/M=0.01

```
   LH2/LO2  MIN LENGTH  PUMP FED              MR=7

VEHICLE MASS  =27215.5 KG    DELTA V=  4815.8 M/S   AVE. ISP=4285.3 N-S/KG

TOTAL PROPELLANT                          19313.96 KG
  USABLE FUEL                   2275.59
  USABLE OXIDIZER              15929.15
  FUEL TRAPPED                    90.20
  OXID TRAPPED                   616.18
  FUEL START-S/D LOSSES           15.42
  OXID START-S/D LOSSES           15.42
  FUEL BOILOFF                   147.99
  OXIDIZER BOILOFF               224.00

OXIDIZER TANKS (NO.= 1)                     107.55
 (TOROIDAL)
  INNER DIA=     1.295 M
  OUTER DIA=     4.267 M
  HEIGHT   =     1.486 M
  VOLUME   =    15.156 M3
  AVG THK  =    .00064 M
  FS = 1.50,  FNOP= 1.50

FUEL TANKS (NO.= 1)                         146.63
 (CYLINDRICAL/SQRT(2) ELLIPTICAL)
  DIAMETER=    4.267 M
  LENGTH  =    3.604 M
  VOLUME  =   37.160 M3
  DOME THK=   .00069 M
  CYL THK =   .00114 M
  FS = 1.50,  FNOP= 1.30

PRESSURANT                                  15.043

PRESSURANT TANKS (NO.= 1)                    80.59
  DIA=     .8822 M
  VOL=      .359 M3
  THK=    .00744 M
  FS = 1.50,  FNOP= 1.10

FUEL TANK INSULATION                         95.43
OXIDIZER TANK INSULATION                     59.75

ENGINES (NO.= 1)                             35.38

COMPONENTS AND LINES                        589.67
ENG. MOUNTS,SUPPORTS                       1305.44

TOTAL WET SYSTEM MASS                      21749.4
TOTAL BURNOUT MASS                          3141.9
   (INCL.NON-USABLE PROP. AND GAS)

MASS FRACTION                                 .837
TOTAL IMPULSE                          78016494.2 N-S

             PRESSURE SCHEDULE(N/M2  )   AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =   .2482E+08    INITIAL CHAMBER PRESSURE =O.
INITIAL OX SYS PRESSURE   =   .1517E+06    FINAL OX SYS PRESSURE    =  .1517E+06
INITIAL FU SYS PRESSURE   =   .1517E+06    FINAL FU SYS PRESSURE    =  .1517E+06
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9 BURNS, CONSTANT ACCELERATION, T/M=0.015

LH2/LO2 MIN LENGTH PUMP FED MR=5

VEHICLE MASS =27215.5 KG DELTA V= 4480.6 M/S AVE. ISP=4471.6 N-S/KG

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TOTAL PROPELLANT                                  18120.74 KG
  USABLE FUEL                        2844.42
  USABLE OXIDIZER                   14222.10
  FUEL TRAPPED                        113.16
  OXID TRAPPED                        553.67
  FUEL START-S/D LOSSES                 7.26
  OXID START-S/D LOSSES                 7.26
  FUEL BOILOFF                        154.10
  OXIDIZER BOILOFF                    218.78

OXIDIZER TANKS (NO.= 1)                             103.62
 (TOROIDAL)
  INNER DIA=     1.510 M
  OUTER DIA=     4.267 M
  HEIGHT    =    1.379 M
  VOLUME    =   13.546 M3
  AVG THK   =   .00064 M
  FS = 1.50,  FNOP= 1.50

FUEL TANKS (NO.= 1)                                 179.82
 (CYLINDRICAL/SQRT(2) ELLIPTICAL)
  DIAMETER=    4.267 M
  LENGTH  =    4.210 M
  VOLUME  =   45.824 M3
  DOME THK=   .00069 M
  CYL THK =   .00114 M
  FS = 1.50,  FNOP= 1.30

PRESSURANT                                          18.090

PRESSURANT TANKS (NO.= 1)                           97.04
  DIA=     .9385 M
  VOL=      .433 M3
  THK=    .00792 M
  FS = 1.50,  FNOP= 1.10

FUEL TANK INSULATION                                109.70
OXIDIZER TANK INSULATION                             57.57

ENGINES (NO.= 1)                                     41.73

COMPONENTS AND LINES                                589.67
ENG. MOUNTS,SUPPORTS                               1293.65

TOTAL WET SYSTEM MASS                              20611.6
TOTAL BURNOUT MASS                                  3157.7
   (INCL.NON-USABLE PROP. AND GAS)

MASS FRACTION                                         .828
TOTAL IMPULSE                                  76318566.3 N-S

             PRESSURE SCHEDULE(N/M2  )  AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =  .2482E+08   INITIAL CHAMBER PRESSURE =0.
INITIAL OX SYS PRESSURE   =  .1517E+06   FINAL OX SYS PRESSURE    =  .1517E+06
INITIAL FU SYS PRESSURE   =  .1517E+06   FINAL FU SYS PRESSURE    =  .1517E+06
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9 BURNS, CONSTANT ACCELERATION, T/M=0.015

```
   LH2/LO2  MIN LENGTH  PUMP FED                   MR=6

VEHICLE MASS  =27215.5 KG    DELTA V=  4480.6 M/S   AVE. ISP=4432.4 N-S/KG

TOTAL PROPELLANT                            18208.04 KG
  USABLE FUEL                   2450.90
  USABLE OXIDIZER              14705.41
  FUEL TRAPPED                    97.70
  OXID TRAPPED                   571.27
  FUEL START-S/D LOSSES            7.26
  OXID START-S/D LOSSES            7.26
  FUEL BOILOFF                   148.65
  OXIDIZER BOILOFF               219.58

OXIDIZER TANKS (NO.= 1)                       104.79
 (TOROIDAL)
  INNER DIA=     1.449 M
  OUTER DIA=     4.267 M
  HEIGHT   =     1.409 M
  VOLUME   =    13.999 M3
  AVG THK  =    .00064 M
  FS = 1.50,  FNOP= 1.50

FUEL TANKS (NO.= 1)                           156.50
 (CYLINDRICAL/SQRT(2) ELLIPTICAL)
  DIAMETER=     4.267 M
  LENGTH  =     3.784 M
  VOLUME  =    39.735 M3
  DOME THK=    .00069 M
  CYL THK =    .00114 M
  FS = 1.50,  FNOP= 1.30

PRESSURANT                                     15.886

PRESSURANT TANKS (NO.= 1)                      85.16
  DIA=     .8985 M
  VOL=      .380 M3
  THK=    .00758 M
  FS = 1.50,  FNOP= 1.10

FUEL TANK INSULATION                           99.67
OXIDIZER TANK INSULATION                       58.22

ENGINES (NO.= 1)                               40.82

COMPONENTS AND LINES                          589.67
ENG. MOUNTS,SUPPORTS                         1293.65

TOTAL WET SYSTEM MASS                        20652.4
TOTAL BURNOUT MASS                            3113.3
   (INCL.NON-USABLE PROP. AND GAS)

MASS FRACTION                                   .831
TOTAL IMPULSE                           76047159.3 N-S

             PRESSURE SCHEDULE(N/M2  )   AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =   .2482E+08    INITIAL CHAMBER PRESSURE =0.
INITIAL OX SYS PRESSURE   =   .1517E+06    FINAL OX SYS PRESSURE    =  .1517E+06
INITIAL FU SYS PRESSURE   =   .1517E+06    FINAL FU SYS PRESSURE    =  .1517E+06
```

9 BURNS, CONSTANT ACCELERATION, T/M=0.015

```
   LH2/LO2  MIN LENGTH  PUMP FED                  MR=7

VEHICLE MASS  =27215.5 KG    DELTA V=  4480.6 M/S   AVE. ISP=4344.1 N-S/KG

TOTAL PROPELLANT                              18411.05 KG
  USABLE FUEL                      2169.68
  USABLE OXIDIZER                 15187.78
  FUEL TRAPPED                       86.02
  OXID TRAPPED                      587.94
  FUEL START-S/D LOSSES               7.26
  OXID START-S/D LOSSES               7.26
  FUEL BOILOFF                      144.75
  OXIDIZER BOILOFF                  220.35

OXIDIZER TANKS (NO.= 1)                         105.90
 (TOROIDAL)
  INNER DIA=     1.389 M
  OUTER DIA=     4.267 M
  HEIGHT   =     1.439 M
  VOLUME   =    14.451 M3
  AVG THK  =    .00064 M
  FS = 1.50,  FNOP= 1.50

FUEL TANKS (NO.= 1)                             139.80
 (CYLINDRICAL/SQRT(2) ELLIPTICAL)
  DIAMETER=    4.267 M
  LENGTH  =    3.479 M
  VOLUME  =   35.375 M3
  DOME THK=   .00069 M
  CYL THK =   .00114 M
  FS = 1.50,  FNOP= 1.30

PRESSURANT                                      14.323

PRESSURANT TANKS (NO.= 1)                        76.73
  DIA=     .8678 M
  VOL=      .342 M3
  THK=    .00732 M
  FS = 1.50,  FNOP= 1.10

FUEL TANK INSULATION                             92.49
OXIDIZER TANK INSULATION                         58.83

ENGINES (NO.= 1)                                 39.01

COMPONENTS AND LINES                            589.67
ENG. MOUNTS,SUPPORTS                           1293.65

TOTAL WET SYSTEM MASS                          20821.4
TOTAL BURNOUT MASS                              3084.4
   (INCL.NON-USABLE PROP. AND GAS)

MASS FRACTION                                     .834
TOTAL IMPULSE                               75406814.4 N-S

             PRESSURE SCHEDULE(N/M2  )   AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =   .2482E+08   INITIAL CHAMBER PRESSURE =0.
INITIAL OX SYS PRESSURE   =   .1517E+06   FINAL OX SYS PRESSURE    =  .1517E+06
INITIAL FU SYS PRESSURE   =   .1517E+06   FINAL FU SYS PRESSURE    =  .1517E+06
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9 BURNS, CONSTANT ACCELERATION, T/M=0.05

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    LH2/LO2  MIN LENGTH  PUMP FED                MR=6

VEHICLE MASS  =27215.5 KG    DELTA V=  4303.8 M/S   AVE. ISP=4491.2 N-S/KG

TOTAL PROPELLANT                           17649.58 KG
  USABLE FUEL                    2375.29
  USABLE OXIDIZER               14251.75
  FUEL TRAPPED                     90.75
  OXID TRAPPED                    530.31
  FUEL START-S/D LOSSES            15.42
  OXID START-S/D LOSSES            15.42
  FUEL BOILOFF                    149.33
  OXIDIZER BOILOFF                221.31

OXIDIZER TANKS (NO.= 1)                      103.66
 (TOROIDAL)
  INNER DIA=     1.508 M
  OUTER DIA=     4.267 M
  HEIGHT   =     1.380 M
  VOLUME   =    13.562 M3
  AVG THK  =    .00064 M
  FS = 1.50,   FNOP= 1.50

FUEL TANKS (NO.= 1)                          152.35
 (CYLINDRICAL/SQRT(2) ELLIPTICAL)
  DIAMETER=    4.267 M
  LENGTH  =    3.708 M
  VOLUME  =   38.652 M3
  DOME THK=   .00069 M
  CYL THK =   .00114 M
  FS = 1.50,   FNOP= 1.30

PRESSURANT                                   15.470

PRESSURANT TANKS (NO.= 1)                     82.94
  DIA=     .8906  M
  VOL=      .370  M3
  THK=    .00751  M
  FS = 1.50,   FNOP= 1.10

FUEL TANK INSULATION                          97.89
OXIDIZER TANK INSULATION                      57.59

ENGINES (NO.= 1)                              64.41

COMPONENTS AND LINES                         554.29
ENG. MOUNTS,SUPPORTS                        1282.31

TOTAL WET SYSTEM MASS                       20060.5
TOTAL BURNOUT MASS                           3032.0
   (INCL.NON-USABLE PROP. AND GAS)

MASS FRACTION                                  .829
TOTAL IMPULSE                          74679413.2 N-S

             PRESSURE SCHEDULE(N/M2  )    AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =    .2482E+08    INITIAL CHAMBER PRESSURE =0.
INITIAL OX SYS PRESSURE   =    .1517E+06    FINAL OX SYS PRESSURE    =  .1517E+06
INITIAL FU SYS PRESSURE   =    .1517E+06    FINAL FU SYS PRESSURE    =  .1517E+06
```

9 BURNS, CONSTANT ACCELERATION, T/M=0.1

LH2/LO2 MIN LENGTH PUMP FED MR=5

VEHICLE MASS =27215.5 KG DELTA V= 4291.6 M/S AVE. ISP=4579.5 N-S/KG

TOTAL PROPELLANT		17423.13 KG
USABLE FUEL	2734.03	
USABLE OXIDIZER	13670.17	
FUEL TRAPPED	108.46	
OXID TRAPPED	530.68	
FUEL START-S/D LOSSES	6.80	
OXID START-S/D LOSSES	6.80	
FUEL BOILOFF	150.86	
OXIDIZER BOILOFF	215.32	

OXIDIZER TANKS (NO.= 1) 102.22
(TOROIDAL)
INNER DIA= 1.580 M
OUTER DIA= 4.267 M
HEIGHT = 1.344 M
VOLUME = 13.024 M3
AVG THK = .00064 M
FS = 1.50, FNOP= 1.50

FUEL TANKS (NO.= 1) 173.14
(CYLINDRICAL/SQRT(2) ELLIPTICAL)
DIAMETER= 4.267 M
LENGTH = 4.088 M
VOLUME = 44.079 M3
DOME THK= .00069 M
CYL THK = .00114 M
FS = 1.50, FNOP= 1.30

PRESSURANT 17.402

PRESSURANT TANKS (NO.= 1) 93.35
DIA= .9265 M
VOL= .416 M3
THK= .00782 M
FS = 1.50, FNOP= 1.10

FUEL TANK INSULATION	106.83
OXIDIZER TANK INSULATION	56.79
ENGINES (NO.= 1)	99.79
COMPONENTS AND LINES	589.67
ENG. MOUNTS,SUPPORTS	1284.12
TOTAL WET SYSTEM MASS	19946.4
TOTAL BURNOUT MASS (INCL.NON-USABLE PROP. AND GAS)	3162.4
MASS FRACTION	.822
TOTAL IMPULSE	75126398.3 N-S

PRESSURE SCHEDULE(N/M2) AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =	.2482E+08	INITIAL CHAMBER PRESSURE =	0.
INITIAL OX SYS PRESSURE =	.1517E+06	FINAL OX SYS PRESSURE =	.1517E+06
INITIAL FU SYS PRESSURE =	.1517E+06	FINAL FU SYS PRESSURE =	.1517E+06

9 BURNS, CONSTANT ACCELERATION, T/M=0.1

LH2/LO2 MIN LENGTH PUMP FED MR=6

VEHICLE MASS =27215.5 KG DELTA V= 4291.6 M/S AVE. ISP=4559.9 N-S/KG

TOTAL PROPELLANT		17463.91 KG
USABLE FUEL	2349.85	
USABLE OXIDIZER	14099.11	
FUEL TRAPPED	93.23	
OXID TRAPPED	546.46	
FUEL START-S/D LOSSES	6.80	
OXID START-S/D LOSSES	6.80	
FUEL BOILOFF	145.58	
OXIDIZER BOILOFF	216.07	

OXIDIZER TANKS (NO.= 1) 103.31
(TOROIDAL)
INNER DIA= 1.526 M
OUTER DIA= 4.267 M
HEIGHT = 1.371 M
VOLUME = 13.426 M3
AVG THK = .00064 M
FS = 1.50, FNOP= 1.50

FUEL TANKS (NO.= 1) 150.36
(CYLINDRICAL/SQRT(2) ELLIPTICAL)
DIAMETER= 4.267 M
LENGTH = 3.672 M
VOLUME = 38.133 M3
DOME THK= .00069 M
CYL THK = .00114 M
FS = 1.50, FNOP= 1.30

PRESSURANT 15.247

PRESSURANT TANKS (NO.= 1) 81.74
DIA= .8863 M
VOL= .365 M3
THK= .00748 M
FS = 1.50, FNOP= 1.10

FUEL TANK INSULATION	97.03
OXIDIZER TANK INSULATION	57.39
ENGINES (NO.= 1)	96.16
COMPONENTS AND LINES	589.67
ENG. MOUNTS,SUPPORTS	1284.12
TOTAL WET SYSTEM MASS	19938.9
TOTAL BURNOUT MASS (INCL.NON-USABLE PROP. AND GAS)	3114.7
MASS FRACTION	.825
TOTAL IMPULSE	75008757.5 N-S

PRESSURE SCHEDULE(N/M2) AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =	.2482E+08	INITIAL CHAMBER PRESSURE =	0.
INITIAL OX SYS PRESSURE =	.1517E+06	FINAL OX SYS PRESSURE =	.1517E+06
INITIAL FU SYS PRESSURE =	.1517E+06	FINAL FU SYS PRESSURE =	.1517E+06

9 BURNS, CONSTANT ACCELERATION, T/M=0.1

LH2/LO2 MIN LENGTH PUMP FED MR=7

VEHICLE MASS =27215.5 KG DELTA V= 4291.6 M/S AVE. ISP=4510.9 N-S/KG

TOTAL PROPELLANT		17570.26 KG
USABLE FUEL	2069.71	
USABLE OXIDIZER	14487.97	
FUEL TRAPPED	82.03	
OXID TRAPPED	558.51	
FUEL START-S/D LOSSES	6.80	
OXID START-S/D LOSSES	6.80	
FUEL BOILOFF	141.72	
OXIDIZER BOILOFF	216.71	

OXIDIZER TANKS (NO.= 1) 104.25
(TOROIDAL)
INNER DIA= 1.478 M
OUTER DIA= 4.267 M
HEIGHT = 1.395 M
VOLUME = 13.788 M3
AVG THK = .00064 M
FS = 1.50, FNOP= 1.50

FUEL TANKS (NO.= 1) 133.75
(CYLINDRICAL/SQRT(2) ELLIPTICAL)
DIAMETER= 4.267 M
LENGTH = 3.369 M
VOLUME = 33.796 M3
DOME THK= .00069 M
CYL THK = .00114 M
FS = 1.50, FNOP= 1.30

PRESSURANT 13.682

PRESSURANT TANKS (NO.= 1) 73.30
DIA= .8547 M
VOL= .327 M3
THK= .00721 M
FS = 1.50, FNOP= 1.10

FUEL TANK INSULATION	89.89
OXIDIZER TANK INSULATION	57.92
ENGINES (NO.= 1)	93.44
COMPONENTS AND LINES	589.67
ENG. MOUNTS,SUPPORTS	1284.12
TOTAL WET SYSTEM MASS	20010.3
TOTAL BURNOUT MASS (INCL.NON-USABLE PROP. AND GAS)	3080.6
MASS FRACTION	.827
TOTAL IMPULSE	74692662.4 N-S

PRESSURE SCHEDULE(N/M2) AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =	.2482E+08	INITIAL CHAMBER PRESSURE =	0.
INITIAL OX SYS PRESSURE =	.1517E+06	FINAL OX SYS PRESSURE =	.1517E+06
INITIAL FU SYS PRESSURE =	.1517E+06	FINAL FU SYS PRESSURE =	.1517E+06

2 BURNS, CONSTANT ACCELERATION, T/M=0.01

N2O4/MMH, MAX. PERF., PUMP FED,

VEHICLE MASS =27215.5 KG   DELTA V= 5516.9 M/S   AVE. ISP=3157.6 N-S/KG

TOTAL PROPELLANT		23159.80 KG
USABLE FUEL	7022.64	
USABLE OXIDIZER	15449.81	
FUEL TRAPPED	214.05	
OXID TRAPPED	468.94	
FUEL START-S/D LOSSES	2.18	
OXID START-S/D LOSSES	2.18	
OXIDIZER TANKS (NO.= 1) (ELLIPSOIDAL)		105.45
DIAMETER= 3.158 M		
LENGTH = 2.233 M		
VOLUME = 11.658 M3		
AVG THK = .00115 M		
FS = 1.50, FNOP= 1.30		
FUEL TANKS (NO.= 1) (ELLIPSOIDAL)		47.92
DIAMETER= 2.868 M		
LENGTH = 2.028 M		
VOLUME = 8.735 M3		
AVG THK = .00064 M		
FS = 1.50, FNOP= 1.30		
PRESSURANT		3.726
PRESSURANT TANKS (NO.= 1)		19.52
DIA= .5499 M		
VOL= .087 M3		
THK= .00464 M		
FS = 1.50, FNOP= 1.10		
ENGINES (NO.= 1)		41.73
COMPONENTS AND LINES		363.33
ENG. MOUNTS, SUPPORTS		958.89
TOTAL WET SYSTEM MASS		24700.4
TOTAL BURNOUT MASS (INCL.NON-USABLE PROP. AND GAS)		2223.6
MASS FRACTION		.910
TOTAL IMPULSE		70962166.6 N-S

PRESSURE SCHEDULE(N/M2) AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =	.2482E+08	INITIAL CHAMBER PRESSURE =	0.
INITIAL OX SYS PRESSURE =	.1379E+06	FINAL OX SYS PRESSURE =	.1379E+06
INITIAL FU SYS PRESSURE =	.1034E+06	FINAL FU SYS PRESSURE =	.1034E+06

2 BURNS, CONSTANT ACCELERATION, T/M=0.05

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   N2O4/MMH, MAX. PERF., PUMP FED,

VEHICLE MASS   =27215.6 KG     DELTA V=  5120.6 M/S    AVE. ISP=3236.0 N-S/KG

TOTAL PROPELLANT                              22283.79 KG
  USABLE FUEL                       6757.10
  USABLE OXIDIZER                  14865.63
  FUEL TRAPPED                       205.98
  OXID TRAPPED                       451.09
  FUEL START-S/D LOSSES                2.00
  OXID START-S/D LOSSES                2.00

OXIDIZER TANKS (NO.= 1)                          101.46
 (ELLIPSOIDAL)
  DIAMETER=     3.117 M
  LENGTH  =     2.204 M
  VOLUME  =    11.217 M3
  AVG THK =    .00114 M
  FS = 1.50,  FNOP= 1.30

FUEL TANKS (NO.= 1)                               46.70
 (ELLIPSOIDAL)
  DIAMETER=     2.832 M
  LENGTH  =     2.002 M
  VOLUME  =     8.405 M3
  AVG THK =    .00064 M
  FS = 1.50,  FNOP= 1.30

PRESSURANT                                        3.588

PRESSURANT TANKS (NO.= 1)                         18.78
  DIA=     .5429 M
  VOL=      .084 M3
  THK=    .00458 M
  FS = 1.50,  FNOP= 1.10


ENGINES (NO.= 1)                                  68.04

COMPONENTS AND LINES                             363.33
ENG. MOUNTS,SUPPORTS                             949.37

TOTAL WET SYSTEM MASS                           23835.1
TOTAL BURNOUT MASS                               2208.3
   (INCL.NON-USABLE PROP. AND GAS)

MASS FRACTION                                      .907
TOTAL IMPULSE                              69975322.3 N-S

             PRESSURE SCHEDULE(N/M2  )   AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =   .2482E+08   INITIAL CHAMBER PRESSURE =0.
INITIAL OX SYS PRESSURE   =   .1379E+06   FINAL OX SYS PRESSURE    =  .1379E+06
INITIAL FU SYS PRESSURE   =   .1034E+06   FINAL FU SYS PRESSURE    =  .1034E+06
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2 BURNS, CONSTANT ACCELERATION, T/M=0.1

N2O4/MMH, MAX. PERF., PUMP FED,

VEHICLE MASS =27215.5 KG DELTA V= 4846.3 M/S AVE. ISP=3265.5 N-S/KG

TOTAL PROPELLANT		21693.20 KG
USABLE FUEL	6576.65	
USABLE OXIDIZER	14468.63	
FUEL TRAPPED	200.98	
OXID TRAPPED	440.22	
FUEL START-S/D LOSSES	3.36	
OXID START-S/D LOSSES	3.36	
OXIDIZER TANKS (NO.= 1)		98.77
(ELLIPSOIDAL)		
DIAMETER= 3.090 M		
LENGTH = 2.185 M		
VOLUME = 10.919 M3		
AVG THK = .00113 M		
FS = 1.50, FNOP= 1.30		
FUEL TANKS (NO.= 1)		45.88
(ELLIPSOIDAL)		
DIAMETER= 2.806 M		
LENGTH = 1.984 M		
VOLUME = 8.183 M3		
AVG THK = .00064 M		
FS = 1.50, FNOP= 1.30		
PRESSURANT		3.493
PRESSURANT TANKS (NO.= 1)		18.28
DIA= .5380 M		
VOL= .082 M3		
THK= .00454 M		
FS = 1.50, FNOP= 1.10		
ENGINES (NO.= 1)		99.79
COMPONENTS AND LINES		363.33
ENG. MOUNTS, SUPPORTS		949.37
TOTAL WET SYSTEM MASS		23272.1
TOTAL BURNOUT MASS		2220.1
(INCL.NON-USABLE PROP. AND GAS)		
MASS FRACTION		.904
TOTAL IMPULSE		68725760.2 N-S

PRESSURE SCHEDULE(N/M2) AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =	.2482E+08	INITIAL CHAMBER PRESSURE =	0.
INITIAL OX SYS PRESSURE =	.1379E+06	FINAL OX SYS PRESSURE =	.1379E+06
INITIAL FU SYS PRESSURE =	.1034E+06	FINAL FU SYS PRESSURE =	.1034E+06

2 BURNS, CONSTANT ACCELERATION, T/M=0.05

N2O4/MMH, MIN. LENGTH, PUMP FED,

VEHICLE MASS =27215.5 KG   DELTA V= 5120.6 M/S   AVE. ISP=3236.0 N-S/KG

TOTAL PROPELLANT		22298.38 KG
USABLE FUEL	6757.10	
USABLE OXIDIZER	14865.63	
FUEL TRAPPED	210.54	
OXID TRAPPED	461.12	
FUEL START-S/D LOSSES	2.00	
OXID START-S/D LOSSES	2.00	
OXIDIZER TANKS (NO.= 1)		107.21
(TOROIDAL)		
INNER DIA= 1.823 M		
OUTER DIA= 4.267 M		
HEIGHT = 1.222 M		
VOLUME = 11.224 M3		
AVG THK = .00081 M		
FS = 1.50, FNOP= 1.30		
FUEL TANKS (NO.= 1)		46.72
(ELLIPSOIDAL)		
DIAMETER= 2.832 M		
LENGTH = 2.003 M		
VOLUME = 8.410 M3		
AVG THK = .00064 M		
FS = 1.50, FNOP= 1.30		
PRESSURANT		3.585
PRESSURANT TANKS (NO.= 1)		18.78
DIA= .5429 M		
VOL= .084 M3		
THK= .00458 M		
FS = 1.50, FNOP= 1.10		
ENGINES (NO.= 1)		65.77
COMPONENTS AND LINES		386.01
ENG. MOUNTS,SUPPORTS		1289.11
TOTAL WET SYSTEM MASS		24215.6
TOTAL BURNOUT MASS		2588.8
(INCL.NON-USABLE PROP. AND GAS)		
MASS FRACTION		.893
TOTAL IMPULSE		69975322.3 N-S

PRESSURE SCHEDULE(N/M2) AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =	.2482E+08	INITIAL CHAMBER PRESSURE =	0.
INITIAL OX SYS PRESSURE =	.1379E+06	FINAL OX SYS PRESSURE =	.1379E+06
INITIAL FU SYS PRESSURE =	.1034E+06	FINAL FU SYS PRESSURE =	.1034E+06

2 BURNS, CONSTANT ACCELERATION, T/M=0.015

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   LCH4/LO2  MAX PERF  PUMP FED

VEHICLE MASS  =27215.5 KG    DELTA V=  5516.9 M/S   AVE. ISP=3491.0 N-S/KG

TOTAL PROPELLANT                          22480.56 KG
  USABLE FUEL                    4567.05
  USABLE OXIDIZER               16898.09
  FUEL TRAPPED                    168.42
  OXID TRAPPED                    612.34
  FUEL START-S/D LOSSES             2.18
  OXID START-S/D LOSSES             2.18
  FUEL BOILOFF                     64.43
  OXIDIZER BOILOFF                165.87

OXIDIZER TANKS (NO.= 1)                      71.63
 (ELLIPSOIDAL)
  DIAMETER=    3.507 M
  LENGTH  =    2.479 M
  VOLUME  =   15.963 M3
  AVG THK =   .00064 M
  FS = 1.50,  FNOP= 1.30

FUEL TANKS (NO.= 1)                          58.27
 (ELLIPSOIDAL)
  DIAMETER=    3.163 M
  LENGTH  =    2.236 M
  VOLUME  =   11.714 M3
  AVG THK =   .00064 M
  FS = 1.50,  FNOP= 1.30

PRESSURANT                                   2.299

PRESSURANT TANKS (NO.= 1)                    11.60
  DIA=     .4624 M
  VOL=      .052 M3
  THK=    .00390 M
  FS = 1.50,  FNOP= 1.10

FUEL TANK INSULATION                         26.15
OXIDIZER TANK INSULATION                     45.92

ENGINES (NO.= 1)                             40.82

COMPONENTS AND LINES                        554.29
ENG. MOUNTS,SUPPORTS                       1343.54

TOTAL WET SYSTEM MASS                      24635.1
TOTAL BURNOUT MASS                          2935.3
   (INCL.NON-USABLE PROP. AND GAS)

MASS FRACTION                                 .871
TOTAL IMPULSE                           74938390.6 N-S

             PRESSURE SCHEDULE(N/M2  )   AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =   .2482E+08    INITIAL CHAMBER PRESSURE =0.
INITIAL OX SYS PRESSURE   =   .1517E+06    FINAL OX SYS PRESSURE    =  .1517E+06
INITIAL FU SYS PRESSURE   =   .1517E+06    FINAL FU SYS PRESSURE    =  .1517E+06
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2 BURNS, CONSTANT ACCELERATION, T/M=0.05

LCH4/LO2 MAX PERF PUMP FED

VEHICLE MASS =27215.5 KG DELTA V= 5120.6 M/S AVE. ISP=3559.7 N-S/KG

TOTAL PROPELLANT		21582.48 KG
USABLE FUEL	4386.93	
USABLE OXIDIZER	16231.64	
FUEL TRAPPED	161.94	
OXID TRAPPED	587.79	
FUEL START-S/D LOSSES	2.00	
OXID START-S/D LOSSES	2.00	
FUEL BOILOFF	58.85	
OXIDIZER BOILOFF	151.33	
OXIDIZER TANKS (NO.= 1) (ELLIPSOIDAL)		69.71
DIAMETER= 3.459 M		
LENGTH = 2.446 M		
VOLUME = 15.326 M3		
AVG THK = .00064 M		
FS = 1.50, FNOP= 1.30		
FUEL TANKS (NO.= 1) (ELLIPSOIDAL)		56.71
DIAMETER= 3.120 M		
LENGTH = 2.206 M		
VOLUME = 11.245 M3		
AVG THK = .00064 M		
FS = 1.50, FNOP= 1.30		
PRESSURANT		8.829
PRESSURANT TANKS (NO.= 1)		47.75
DIA= .7409 M		
VOL= .213 M3		
THK= .00625 M		
FS = 1.50, FNOP= 1.10		
FUEL TANK INSULATION		25.45
OXIDIZER TANK INSULATION		44.69
ENGINES (NO.= 1)		63.50
COMPONENTS AND LINES		554.29
ENG. MOUNTS,SUPPORTS		1331.29
TOTAL WET SYSTEM MASS		23784.7
TOTAL BURNOUT MASS (INCL.NON-USABLE PROP. AND GAS)		2951.9
MASS FRACTION		.867
TOTAL IMPULSE		73398260.4 N-S

PRESSURE SCHEDULE(N/M2) AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =	.2482E+08	INITIAL CHAMBER PRESSURE =	0.
INITIAL OX SYS PRESSURE =	.1517E+06	FINAL OX SYS PRESSURE =	.1517E+06
INITIAL FU SYS PRESSURE =	.1517E+06	FINAL FU SYS PRESSURE =	.1517E+06

2 BURNS, CONSTANT ACCELERATION, T/M=0.1

LCH4/LO2 MAX PERF PUMP FED

VEHICLE MASS =27215.5 KG   DELTA V= 4846.3 M/S   AVE. ISP=3579.3 N-S/KG

TOTAL PROPELLANT		20990.64 KG
USABLE FUEL	4266.74	
USABLE OXIDIZER	15786.95	
FUEL TRAPPED	153.37	
OXID TRAPPED	573.42	
FUEL START-S/D LOSSES	3.08	
OXID START-S/D LOSSES	3.08	
FUEL BOILOFF	57.11	
OXIDIZER BOILOFF	146.87	
OXIDIZER TANKS (NO.= 1) (ELLIPSOIDAL)		68.44
DIAMETER= 3.428 M		
LENGTH = 2.424 M		
VOLUME = 14.908 M3		
AVG THK = .00064 M		
FS = 1.50, FNOP= 1.30		
FUEL TANKS (NO.= 1) (ELLIPSOIDAL)		55.64
DIAMETER= 3.091 M		
LENGTH = 2.185 M		
VOLUME = 10.929 M3		
AVG THK = .00064 M		
FS = 1.50, FNOP= 1.30		
PRESSURANT		8.588
PRESSURANT TANKS (NO.= 1)		46.44
DIA= .7341 M		
VOL= .207 M3		
THK= .00619 M		
FS = 1.50, FNOP= 1.10		
FUEL TANK INSULATION		24.97
OXIDIZER TANK INSULATION		43.87
ENGINES (NO.= 1)		93.44
COMPONENTS AND LINES		554.29
ENG. MOUNTS,SUPPORTS		1322.22
TOTAL WET SYSTEM MASS		23208.5
TOTAL BURNOUT MASS (INCL.NON-USABLE PROP. AND GAS)		2944.7
MASS FRACTION		.864
TOTAL IMPULSE		71780720.3 N-S

PRESSURE SCHEDULE(N/M2) AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =	.2482E+08	INITIAL CHAMBER PRESSURE =	0.
INITIAL OX SYS PRESSURE =	.1517E+06	FINAL OX SYS PRESSURE =	.1517E+06
INITIAL FU SYS PRESSURE =	.1517E+06	FINAL FU SYS PRESSURE =	.1517E+06

2 BURNS, CONSTANT ACCELERATION, T/M=0.01

LCH4/LO2 MIN LENGTH PUMP FED

VEHICLE MASS =27215.5 KG DELTA V= 5638.8 M/S AVE. ISP=3461.6 N-S/KG

TOTAL PROPELLANT		22809.24 KG
USABLE FUEL	4620.68	
USABLE OXIDIZER	17096.50	
FUEL TRAPPED	177.61	
OXID TRAPPED	647.10	
FUEL START-S/D LOSSES	1.45	
OXID START-S/D LOSSES	1.45	
FUEL BOILOFF	69.19	
OXIDIZER BOILOFF	195.26	
OXIDIZER TANKS (NO.= 1)		114.81
(TOROIDAL)		
INNER DIA= 1.155 M		
OUTER DIA= 4.267 M		
HEIGHT = 1.556 M		
VOLUME = 16.200 M3		
AVG THK = .00066 M		
FS = 1.50, FNOP= 1.50		
FUEL TANKS (NO.= 1)		58.81
(ELLIPSOIDAL)		
DIAMETER= 3.177 M		
LENGTH = 2.247 M		
VOLUME = 11.877 M3		
AVG THK = .00064 M		
FS = 1.50, FNOP= 1.30		
PRESSURANT		9.314
PRESSURANT TANKS (NO.= 1)		50.37
DIA= .7542 M		
VOL= .225 M3		
THK= .00636 M		
FS = 1.50, FNOP= 1.10		
FUEL TANK INSULATION		26.39
OXIDIZER TANK INSULATION		60.99
ENGINES (NO.= 1)		36.29
COMPONENTS AND LINES		584.23
ENG. MOUNTS, SUPPORTS		1340.82
TOTAL WET SYSTEM MASS		25091.3
TOTAL BURNOUT MASS		3106.7
(INCL.NON-USABLE PROP. AND GAS)		
MASS FRACTION		.866
TOTAL IMPULSE		75179337.4 N-S

PRESSURE SCHEDULE(N/M2) AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =	.2482E+08	INITIAL CHAMBER PRESSURE =	0.
INITIAL OX SYS PRESSURE =	.1517E+06	FINAL OX SYS PRESSURE =	.1517E+06
INITIAL FU SYS PRESSURE =	.1517E+06	FINAL FU SYS PRESSURE =	.1517E+06

2 BURNS, CONSTANT ACCELERATION, T/M=0.05

LCH4/LO2 MIN LENGTH PUMP FED

VEHICLE MASS =27215.5 KG DELTA V= 5120.6 M/S AVE. ISP=3559.7 N-S/KG

TOTAL PROPELLANT		21623.47 KG
USABLE FUEL	4384.44	
USABLE OXIDIZER	16222.42	
FUEL TRAPPED	169.23	
OXID TRAPPED	616.82	
FUEL START-S/D LOSSES	2.00	
OXID START-S/D LOSSES	2.00	
FUEL BOILOFF	58.87	
OXIDIZER BOILOFF	167.71	
OXIDIZER TANKS (NO.= 1)		108.02
(TOROIDAL)		
INNER DIA= 1.268 M		
OUTER DIA= 4.267 M		
HEIGHT = 1.500 M		
VOLUME = 15.359 M3		
AVG THK = .00064 M		
FS = 1.50, FNOP= 1.50		
FUEL TANKS (NO.= 1)		56.75
(ELLIPSOIDAL)		
DIAMETER= 3.121 M		
LENGTH = 2.207 M		
VOLUME = 11.256 M3		
AVG THK = .00064 M		
FS = 1.50, FNOP= 1.30		
PRESSURANT		8.829
PRESSURANT TANKS (NO.= 1)		47.74
DIA= .7409 M		
VOL= .213 M3		
THK= .00625 M		
FS = 1.50, FNOP= 1.10		
FUEL TANK INSULATION		25.47
OXIDIZER TANK INSULATION		60.00
ENGINES (NO.= 1)		64.41
COMPONENTS AND LINES		584.23
ENG. MOUNTS,SUPPORTS		1322.68
TOTAL WET SYSTEM MASS		23901.6
TOTAL BURNOUT MASS		3064.2
(INCL.NON-USABLE PROP. AND GAS)		
MASS FRACTION		.862
TOTAL IMPULSE		73356531.4 N-S

PRESSURE SCHEDULE(N/M2) AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =	.2482E+08	INITIAL CHAMBER PRESSURE =	0.
INITIAL OX SYS PRESSURE =	.1517E+06	FINAL OX SYS PRESSURE =	.1517E+06
INITIAL FU SYS PRESSURE =	.1517E+06	FINAL FU SYS PRESSURE =	.1517E+06

2 BURNS, CONSTANT ACCELERATION, T/M=0.1

LCH4/LO2 MIN LENGTH PUMP FED

VEHICLE MASS =27215.5 KG   DELTA V= 4846.3 M/S   AVE. ISP=3579.3 N-S/KG

TOTAL PROPELLANT		21011.80 KG
USABLE FUEL	4264.28	
USABLE OXIDIZER	15777.82	
FUEL TRAPPED	160.21	
OXID TRAPPED	582.85	
FUEL START-S/D LOSSES	3.08	
OXID START-S/D LOSSES	3.08	
FUEL BOILOFF	57.12	
OXIDIZER BOILOFF	163.36	
OXIDIZER TANKS (NO.= 1)		107.02
(TOROIDAL)		
INNER DIA= 1.326 M		
OUTER DIA= 4.267 M		
HEIGHT = 1.471 M		
VOLUME = 14.924 M3		
AVG THK = .00064 M		
FS = 1.50, FNOP= 1.50		
FUEL TANKS (NO.= 1)		55.68
(ELLIPSOIDAL)		
DIAMETER= 3.092 M		
LENGTH = 2.186 M		
VOLUME = 10.940 M3		
AVG THK = .00064 M		
FS = 1.50, FNOP= 1.30		
PRESSURANT		8.588
PRESSURANT TANKS (NO.= 1)		46.44
DIA= .7341 M		
VOL= .207 M3		
THK= .00619 M		
FS = 1.50, FNOP= 1.10		
FUEL TANK INSULATION		24.99
OXIDIZER TANK INSULATION		59.45
ENGINES (NO.= 1)		93.44
COMPONENTS AND LINES		584.23
ENG. MOUNTS, SUPPORTS		1322.68
TOTAL WET SYSTEM MASS		23314.3
TOTAL BURNOUT MASS		3045.6
(INCL.NON-USABLE PROP. AND GAS)		
MASS FRACTION		.860
TOTAL IMPULSE		71739197.4 N-S

PRESSURE SCHEDULE(N/M2) AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =	.2482E+08	INITIAL CHAMBER PRESSURE =	0.
INITIAL OX SYS PRESSURE =	.1517E+06	FINAL OX SYS PRESSURE =	.1517E+06
INITIAL FU SYS PRESSURE =	.1517E+06	FINAL FU SYS PRESSURE =	.1517E+06

2 BURNS, CONSTANT ACCELERATION, T/M=0.015

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LH2/LO2  MAX PERF  PUMP FED

VEHICLE MASS  =27215.5 KG    DELTA V=  5516.9 M/S    AVE. ISP=4354.0 N-S/KG

TOTAL PROPELLANT                                20365.10 KG
  USABLE FUEL                       2768.85
  USABLE OXIDIZER                  16613.10
  FUEL TRAPPED                       100.47
  OXID TRAPPED                       587.41
  FUEL START-S/D LOSSES                2.18
  OXID START-S/D LOSSES                2.18
  FUEL BOILOFF                       125.65
  OXIDIZER BOILOFF                   165.27

OXIDIZER TANKS (NO.= 1)                            81.68
 (ELLIPSOIDAL)
  DIAMETER=     3.486 M
  LENGTH   =    2.465 M
  VOLUME   =   15.683 M3
  AVG THK  =   .00064 M
  FS = 1.50,  FNOP= 1.50

FUEL TANKS (NO.= 1)                               199.58
 (CYLINDRICAL/SQRT(2) ELLIPTICAL)
  DIAMETER=     4.267 M
  LENGTH   =    4.085 M
  VOLUME   =   44.035 M3
  DOME THK=    .00069 M
  CYL THK  =   .00114 M
  FS = 1.50,  FNOP= 1.50

PRESSURANT                                         17.680

PRESSURANT TANKS (NO.= 1)                          94.79
  DIA=     .9312 M
  VOL=      .423 M3
  THK=    .00786 M
  FS = 1.50,  FNOP= 1.10

FUEL TANK INSULATION                              106.76
OXIDIZER TANK INSULATION                           45.38

ENGINES (NO.= 1)                                   40.82

COMPONENTS AND LINES                              554.29
ENG. MOUNTS,SUPPORTS                             1326.30

TOTAL WET SYSTEM MASS                           22832.4
TOTAL BURNOUT MASS                               3155.2
   (INCL.NON-USABLE PROP. AND GAS)

MASS FRACTION                                      .849
TOTAL IMPULSE                              84391911.1 N-S

            PRESSURE SCHEDULE(N/M2  )   AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =    .2482E+08    INITIAL CHAMBER PRESSURE =0.
INITIAL OX SYS PRESSURE   =    .1517E+06    FINAL OX SYS PRESSURE    =  .1517E+06
INITIAL FU SYS PRESSURE   =    .1517E+06    FINAL FU SYS PRESSURE    =  .1517E+06
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2 BURNS, CONSTANT ACCELERATION, T/M=0.05

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    LH2/LO2   MAX PERF   PUMP FED

VEHICLE MASS   =27215.5 KG    DELTA V=  5120.6 M/S    AVE. ISP=4481.4 N-S/KG

TOTAL PROPELLANT                              19312.29 KG
  USABLE FUEL                       2625.28
  USABLE OXIDIZER                  15751.66
  FUEL TRAPPED                        97.63
  OXID TRAPPED                       569.81
  FUEL START-S/D LOSSES                1.45
  OXID START-S/D LOSSES                1.45
  FUEL BOILOFF                       114.62
  OXIDIZER BOILOFF                   150.39

OXIDIZER TANKS (NO.= 1)                          78.85
 (ELLIPSOIDAL)
  DIAMETER=     3.425  M
  LENGTH   =    2.422  M
  VOLUME   =   14.875  M3
  AVG THK  =   .00064  M
  FS = 1.50,  FNOP= 1.50

FUEL TANKS (NO.= 1)                             189.31
 (CYLINDRICAL/SQRT(2) ELLIPTICAL)
  DIAMETER=     4.267  M
  LENGTH   =    3.922  M
  VOLUME   =   41.711  M3
  DOME THK=    .00069  M
  CYL THK  =   .00114  M
  FS = 1.50,  FNOP= 1.50

PRESSURANT                                       16.736

PRESSURANT TANKS (NO.= 1)                        89.72
  DIA=     .9143  M
  VOL=      .400  M3
  THK=    .00771  M
  FS = 1.50,  FNOP= 1.10

FUEL TANK INSULATION                            102.93
OXIDIZER TANK INSULATION                         43.81

ENGINES (NO.= 1)                                 41.73

COMPONENTS AND LINES                            554.29
ENG. MOUNTS,SUPPORTS                           1284.12

TOTAL WET SYSTEM MASS                          21713.8
TOTAL BURNOUT MASS                              3068.9
   (INCL.NON-USABLE PROP. AND GAS)

MASS FRACTION                                     .846
TOTAL IMPULSE                              82358782.8 N-S

             PRESSURE SCHEDULE(N/M2  )   AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =   .2482E+08    INITIAL CHAMBER PRESSURE =0.
INITIAL OX SYS PRESSURE   =   .1517E+06    FINAL OX SYS PRESSURE    =  .1517E+06
INITIAL FU SYS PRESSURE   =   .1517E+06    FINAL FU SYS PRESSURE    =  .1517E+06
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2 BURNS, CONSTANT ACCELERATION, T/M=0.1

LH2/LO2 MAX PERF PUMP FED

VEHICLE MASS =27215.5 KG DELTA V= 4846.3 M/S AVE. ISP=4520.7 N-S/KG

TOTAL PROPELLANT		18661.00 KG
USABLE FUEL	2535.52	
USABLE OXIDIZER	15213.12	
FUEL TRAPPED	95.28	
OXID TRAPPED	556.27	
FUEL START-S/D LOSSES	2.00	
OXID START-S/D LOSSES	2.00	
FUEL BOILOFF	111.06	
OXIDIZER BOILOFF	145.76	

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OXIDIZER TANKS (NO.= 1)                        77.06
 (ELLIPSOIDAL)
  DIAMETER=    3.386 M
  LENGTH  =    2.394 M
  VOLUME  =   14.373 M3
  AVG THK =   .00064 M
  FS = 1.50,  FNOP= 1.50

FUEL TANKS (NO.= 1)                           183.13
 (CYLINDRICAL/SQRT(2) ELLIPTICAL)
  DIAMETER=    4.267 M
  LENGTH  =    3.825 M
  VOLUME  =   40.313 M3
  DOME THK=   .00069 M
  CYL THK =   .00114 M
  FS = 1.50,  FNOP= 1.50

PRESSURANT                                    16.169

PRESSURANT TANKS (NO.= 1)                      86.68
  DIA=    .9039 M
  VOL=     .387 M3
  THK=   .00763 M
  FS = 1.50,  FNOP= 1.10

FUEL TANK INSULATION                          100.63
OXIDIZER TANK INSULATION                       42.82

ENGINES (NO.= 1)                               53.52

COMPONENTS AND LINES                          554.29
ENG. MOUNTS,SUPPORTS                         1307.25

TOTAL WET SYSTEM MASS                        21082.6
TOTAL BURNOUT MASS                            3073.1
   (INCL.NON-USABLE PROP. AND GAS)

MASS FRACTION                                   .842
TOTAL IMPULSE                          80239156.2 N-S

             PRESSURE SCHEDULE(N/M2  )   AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =   .2482E+08   INITIAL CHAMBER PRESSURE =0.
INITIAL OX SYS PRESSURE   =   .1517E+06   FINAL OX SYS PRESSURE    =  .1517E+06
INITIAL FU SYS PRESSURE   =   .1517E+06   FINAL FU SYS PRESSURE    =  .1517E+06
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2 BURNS, CONSTANT ACCELERATION, T/M=0.01

LH2/LO2 MIN LENGTH PUMP FED

VEHICLE MASS =27215.5 KG DELTA V= 5638.8 M/S AVE. ISP=4295.1 N-S/KG

TOTAL PROPELLANT		20796.48 KG
USABLE FUEL	2815.71	
USABLE OXIDIZER	16894.24	
FUEL TRAPPED	109.94	
OXID TRAPPED	643.84	
FUEL START-S/D LOSSES	1.45	
OXID START-S/D LOSSES	1.45	
FUEL BOILOFF	134.83	
OXIDIZER BOILOFF	195.02	

OXIDIZER TANKS (NO.= 1) 113.24
(TOROIDAL)
INNER DIA= 1.180 M
OUTER DIA= 4.267 M
HEIGHT = 1.544 M
VOLUME = 16.014 M3
AVG THK = .00066 M
FS = 1.50, FNOP= 1.50

FUEL TANKS (NO.= 1) 176.62
(CYLINDRICAL/SQRT(2) ELLIPTICAL)
DIAMETER= 4.267 M
LENGTH = 4.151 M
VOLUME = 44.987 M3
DOME THK= .00069 M
CYL THK = .00114 M
FS = 1.50, FNOP= 1.30

PRESSURANT 18.016

PRESSURANT TANKS (NO.= 1) 96.58
DIA= .9370 M
VOL= .431 M3
THK= .00791 M
FS = 1.50, FNOP= 1.10

FUEL TANK INSULATION	108.33
OXIDIZER TANK INSULATION	60.78
ENGINES (NO.= 1)	26.31
COMPONENTS AND LINES	584.23
ENG. MOUNTS, SUPPORTS	1317.23
TOTAL WET SYSTEM MASS	23297.8
TOTAL BURNOUT MASS (INCL.NON-USABLE PROP. AND GAS)	3255.1
MASS FRACTION	.846
TOTAL IMPULSE	84660346.7 N-S

PRESSURE SCHEDULE(N/M2) AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =	.2482E+08	INITIAL CHAMBER PRESSURE =	0.
INITIAL OX SYS PRESSURE =	.1517E+06	FINAL OX SYS PRESSURE =	.1517E+06
INITIAL FU SYS PRESSURE =	.1517E+06	FINAL FU SYS PRESSURE =	.1517E+06

2 BURNS, CONSTANT ACCELERATION, T/M=0.05

LH2/LO2 MIN LENGTH PUMP FED

VEHICLE MASS =27215.5 KG DELTA V= 5120.6 M/S AVE. ISP=4481.4 N-S/KG

TOTAL PROPELLANT		19353.76 KG
USABLE FUEL	2623.75	
USABLE OXIDIZER	15742.49	
FUEL TRAPPED	102.64	
OXID TRAPPED	600.20	
FUEL START-S/D LOSSES	1.45	
OXID START-S/D LOSSES	1.45	
FUEL BOILOFF	114.66	
OXIDIZER BOILOFF	167.10	
OXIDIZER TANKS (NO.= 1)		106.99
(TOROIDAL)		
INNER DIA= 1.328 M		
OUTER DIA= 4.267 M		
HEIGHT = 1.470 M		
VOLUME = 14.909 M3		
AVG THK = .00064 M		
FS = 1.50, FNOP= 1.50		
FUEL TANKS (NO.= 1)		164.27
(CYLINDRICAL/SQRT(2) ELLIPTICAL)		
DIAMETER= 4.267 M		
LENGTH = 3.926 M		
VOLUME = 41.763 M3		
DOME THK= .00069 M		
CYL THK = .00114 M		
FS = 1.50, FNOP= 1.30		
PRESSURANT		16.729
PRESSURANT TANKS (NO.= 1)		89.68
DIA= .9142 M		
VOL= .400 M3		
THK= .00771 M		
FS = 1.50, FNOP= 1.10		
FUEL TANK INSULATION		103.01
OXIDIZER TANK INSULATION		59.44
ENGINES (NO.= 1)		41.73
COMPONENTS AND LINES		584.23
ENG. MOUNTS, SUPPORTS		1293.65
TOTAL WET SYSTEM MASS		21813.5
TOTAL BURNOUT MASS		3162.6
(INCL.NON-USABLE PROP. AND GAS)		
MASS FRACTION		.842
TOTAL IMPULSE		82310830.7 N-S

PRESSURE SCHEDULE(N/M2) AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =	.2482E+08	INITIAL CHAMBER PRESSURE =	0.
INITIAL OX SYS PRESSURE =	.1517E+06	FINAL OX SYS PRESSURE =	.1517E+06
INITIAL FU SYS PRESSURE =	.1517E+06	FINAL FU SYS PRESSURE =	.1517E+06

2 BURNS, CONSTANT ACCELERATION, T/M=0.1

LH2/LO2 MIN LENGTH PUMP FED

VEHICLE MASS =27215.5 KG   DELTA V= 4846.3 M/S   AVE. ISP=4520.7 N-S/KG

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TOTAL PROPELLANT                                  18702.78 KG
  USABLE FUEL                       2534.01
  USABLE OXIDIZER                  15204.07
  FUEL TRAPPED                       100.30
  OXID TRAPPED                       586.67
  FUEL START-S/D LOSSES                2.00
  OXID START-S/D LOSSES                2.00
  FUEL BOILOFF                       111.10
  OXIDIZER BOILOFF                   162.64

OXIDIZER TANKS (NO.= 1)                             105.80
 (TOROIDAL)
  INNER DIA=     1.395 M
  OUTER DIA=     4.267 M
  HEIGHT   =     1.436 M
  VOLUME   =    14.407 M3
  AVG THK  =    .00064 M
  FS = 1.50,  FNOP= 1.50

FUEL TANKS (NO.= 1)                                 158.91
 (CYLINDRICAL/SQRT(2) ELLIPTICAL)
  DIAMETER=     4.267 M
  LENGTH  =     3.828 M
  VOLUME  =    40.366 M3
  DOME THK=    .00069 M
  CYL THK =    .00114 M
  FS = 1.50,  FNOP= 1.30

PRESSURANT                                          16.163

PRESSURANT TANKS (NO.= 1)                           86.64
  DIA=     .9037 M
  VOL=      .386 M3
  THK=    .00763 M
  FS = 1.50,  FNOP= 1.10

FUEL TANK INSULATION                               100.71
OXIDIZER TANK INSULATION                            58.78

ENGINES (NO.= 1)                                    53.52

COMPONENTS AND LINES                               584.23
ENG. MOUNTS,SUPPORTS                              1293.65

TOTAL WET SYSTEM MASS                             21161.2
TOTAL BURNOUT MASS                                 3145.4
   (INCL.NON-USABLE PROP. AND GAS)

MASS FRACTION                                        .838
TOTAL IMPULSE                                  80191452.1 N-S

             PRESSURE SCHEDULE(N/M2  )  AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =  .2482E+08   INITIAL CHAMBER PRESSURE =0.
INITIAL OX SYS PRESSURE   =  .1517E+06   FINAL OX SYS PRESSURE    =  .1517E+06
INITIAL FU SYS PRESSURE   =  .1517E+06   FINAL FU SYS PRESSURE    =  .1517E+06
```

9 BURNS, CONSTANT THRUST, T/M=0.05

N2O4/MMH, MAX. PERF., PUMP FED,

VEHICLE MASS =27215.5 KG DELTA V= 4511.0 M/S AVE. ISP=3245.9 N-S/KG

TOTAL PROPELLANT		21062.15 KG
USABLE FUEL	6385.92	
USABLE OXIDIZER	14049.03	
FUEL TRAPPED	191.63	
OXID TRAPPED	420.14	
FUEL START-S/D LOSSES	7.71	
OXID START-S/D LOSSES	7.71	
OXIDIZER TANKS (NO.= 1)		95.88
(ELLIPSOIDAL)		
DIAMETER= 3.059 M		
LENGTH = 2.163 M		
VOLUME = 10.600 M3		
AVG THK = .00112 M		
FS = 1.50, FNOP= 1.30		
FUEL TANKS (NO.= 1)		44.99
(ELLIPSOIDAL)		
DIAMETER= 2.779 M		
LENGTH = 1.965 M		
VOLUME = 7.947 M3		
AVG THK = .00064 M		
FS = 1.50, FNOP= 1.30		
PRESSURANT		3.390
PRESSURANT TANKS (NO.= 1)		17.76
DIA= .5328 M		
VOL= .079 M3		
THK= .00450 M		
FS = 1.50, FNOP= 1.10		
ENGINES (NO.= 1)		39.92
COMPONENTS AND LINES		363.33
ENG. MOUNTS,SUPPORTS		943.02
TOTAL WET SYSTEM MASS		22570.4
TOTAL BURNOUT MASS		2120.1
(INCL.NON-USABLE PROP. AND GAS)		
MASS FRACTION		.905
TOTAL IMPULSE		66331859.6 N-S

PRESSURE SCHEDULE(N/M2) AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =	.2482E+08	INITIAL CHAMBER PRESSURE =	0.
INITIAL OX SYS PRESSURE =	.1379E+06	FINAL OX SYS PRESSURE =	.1379E+06
INITIAL FU SYS PRESSURE =	.1034E+06	FINAL FU SYS PRESSURE =	.1034E+06

9 BURNS, CONSTANT THRUST, T/M=0.01

```
LCH4/LO2  MAX PERF  PUMP FED

VEHICLE MASS  =27215.5 KG   DELTA V=  5334.0 M/S   AVE. ISP=3466.5 N-S/KG

TOTAL PROPELLANT                               22372.51 KG
  USABLE FUEL                       4516.80
  USABLE OXIDIZER                  16712.17
  FUEL TRAPPED                       166.69
  OXID TRAPPED                       606.33
  FUEL START-S/D LOSSES                7.26
  OXID START-S/D LOSSES                7.26
  FUEL BOILOFF                        98.96
  OXIDIZER BOILOFF                   257.03

OXIDIZER TANKS (NO.= 1)                           71.37
 (ELLIPSOIDAL)
  DIAMETER=     3.500 M
  LENGTH  =     2.475 M
  VOLUME  =    15.877 M3
  AVG THK =    .00064 M
  FS = 1.50,   FNOP= 1.30

FUEL TANKS (NO.= 1)                               58.17
 (ELLIPSOIDAL)
  DIAMETER=     3.160 M
  LENGTH  =     2.235 M
  VOLUME  =    11.684 M3
  AVG THK =    .00064 M
  FS = 1.50,   FNOP= 1.30

PRESSURANT                                        9.149

PRESSURANT TANKS (NO.= 1)                         49.47
  DIA=     .7497 M
  VOL=      .221 M3
  THK=    .00633 M
  FS = 1.50,   FNOP= 1.10

FUEL TANK INSULATION                              26.11
OXIDIZER TANK INSULATION                          45.75

ENGINES (NO.= 1)                                  25.40

COMPONENTS AND LINES                             554.29
ENG. MOUNTS,SUPPORTS                            1342.18

TOTAL WET SYSTEM MASS                           24554.4
TOTAL BURNOUT MASS                               2954.9
   (INCL.NON-USABLE PROP. AND GAS)

MASS FRACTION                                      .865
TOTAL IMPULSE                             73593423.5 N-S

            PRESSURE SCHEDULE(N/M2  )   AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =   .2482E+08   INITIAL CHAMBER PRESSURE =0.
INITIAL OX SYS PRESSURE   =   .1517E+06   FINAL OX SYS PRESSURE    =  .1517E+06
INITIAL FU SYS PRESSURE   =   .1517E+06   FINAL FU SYS PRESSURE    =  .1517E+06
```

9 BURNS, CONSTANT THRUST, T/M=0.05

LCH4/LO2 MAX PERF PUMP FED

VEHICLE MASS =27215.5 KG DELTA V= 4511.0 M/S AVE. ISP=3564.6 N-S/KG

TOTAL PROPELLANT		20420.16 KG
USABLE FUEL	4129.53	
USABLE OXIDIZER	15279.25	
FUEL TRAPPED	153.51	
OXID TRAPPED	559.61	
FUEL START-S/D LOSSES	9.98	
OXID START-S/D LOSSES	9.98	
FUEL BOILOFF	77.49	
OXIDIZER BOILOFF	200.80	

```
OXIDIZER TANKS (NO.= 1)                          67.16
 (ELLIPSOIDAL)
  DIAMETER=     3.395 M
  LENGTH  =     2.401 M
  VOLUME  =    14.492 M3
  AVG THK =    .00064 M
  FS = 1.50,  FNOP= 1.30

FUEL TANKS (NO.= 1)                              54.73
 (ELLIPSOIDAL)
  DIAMETER=     3.065 M
  LENGTH  =     2.167 M
  VOLUME  =    10.661 M3
  AVG THK =    .00064 M
  FS = 1.50,  FNOP= 1.30

PRESSURANT                                       8.349

PRESSURANT TANKS (NO.= 1)                        45.15
  DIA=     .7272 M
  VOL=      .201 M3
  THK=    .00614 M
  FS = 1.50,  FNOP= 1.10

FUEL TANK INSULATION                             24.56
OXIDIZER TANK INSULATION                         43.05

ENGINES (NO.= 1)                                 39.92

COMPONENTS AND LINES                            554.29
ENG. MOUNTS,SUPPORTS                           1327.21

TOTAL WET SYSTEM MASS                          22584.6
TOTAL BURNOUT MASS                              2877.5
   (INCL.NON-USABLE PROP. AND GAS)

MASS FRACTION                                     .859
TOTAL IMPULSE                            69186788.7 N-S
```

PRESSURE SCHEDULE(N/M2) AT T=294.4 K

GAS TANK LOCK-UP PRESSURE	=	.2482E+08	INITIAL CHAMBER PRESSURE	=0.	
INITIAL OX SYS PRESSURE	=	.1517E+06	FINAL OX SYS PRESSURE	=	.1517E+06
INITIAL FU SYS PRESSURE	=	.1517E+06	FINAL FU SYS PRESSURE	=	.1517E+06

9 BURNS, CONSTANT THRUST, T/M=0.1

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    LCH4/LO2  MAX PERF  PUMP FED

VEHICLE MASS  =27215.5 KG    DELTA V=  4419.6 M/S   AVE. ISP=3584.2 N-S/KG

TOTAL PROPELLANT                           20153.78 KG
  USABLE FUEL                   4076.11
  USABLE OXIDIZER              15081.61
  FUEL TRAPPED                   150.76
  OXID TRAPPED                   549.17
  FUEL START-S/D LOSSES           10.89
  OXID START-S/D LOSSES           10.89
  FUEL BOILOFF                    76.39
  OXIDIZER BOILOFF               197.96

OXIDIZER TANKS (NO.= 1)                       66.57
 (ELLIPSOIDAL)
  DIAMETER=     3.380 M
  LENGTH  =     2.390 M
  VOLUME  =    14.303 M3
  AVG THK =    .00064 M
  FS = 1.50,  FNOP= 1.30

FUEL TANKS (NO.= 1)                           54.26
 (ELLIPSOIDAL)
  DIAMETER=     3.052 M
  LENGTH  =     2.158 M
  VOLUME  =    10.524 M3
  AVG THK =    .00064 M
  FS = 1.50,  FNOP= 1.30

PRESSURANT                                    8.242

PRESSURANT TANKS (NO.= 1)                     44.57
  DIA=     .7241 M
  VOL=      .199 M3
  THK=    .00611 M
  FS = 1.50,  FNOP= 1.10

FUEL TANK INSULATION                          24.35
OXIDIZER TANK INSULATION                      42.68

ENGINES (NO.= 1)                              50.80

COMPONENTS AND LINES                         554.29
ENG. MOUNTS,SUPPORTS                        1322.22

TOTAL WET SYSTEM MASS                       22321.8
TOTAL BURNOUT MASS                           2867.9
   (INCL.NON-USABLE PROP. AND GAS)

MASS FRACTION                                  .858
TOTAL IMPULSE                            68667578.9 N-S

             PRESSURE SCHEDULE(N/M2  )   AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =   .2482E+08   INITIAL CHAMBER PRESSURE =0.
INITIAL OX SYS PRESSURE   =   .1517E+06   FINAL OX SYS PRESSURE    =  .1517E+06
INITIAL FU SYS PRESSURE   =   .1517E+06   FINAL FU SYS PRESSURE    =  .1517E+06
```

9 BURNS, CONSTANT THRUST, T/M=0.01

```
    LH2/LO2   MAX PERF   PRESS FED

VEHICLE MASS   =27215.5 KG     DELTA V=   5334.0 M/S    AVE. ISP=4270.6 N-S/KG

TOTAL PROPELLANT                               20403.46 KG
  USABLE FUEL                       2748.98
  USABLE OXIDIZER                  16493.86
  FUEL TRAPPED                       101.80
  OXID TRAPPED                       597.66
  FUEL START-S/D LOSSES                7.26
  OXID START-S/D LOSSES                7.26
  FUEL BOILOFF                       190.18
  OXIDIZER BOILOFF                   256.47

OXIDIZER TANKS (NO.= 1)                           439.43
 (ELLIPSOIDAL)
  DIAMETER=     3.485 M
  LENGTH  =     2.464 M
  VOLUME  =    15.671 M3
  AVG THK =    .00394 M
  FS = 1.50,   FNOP= 1.30

FUEL TANKS (NO.= 1)                              1318.83
 (CYLINDRICAL/SQRT(2) ELLIPTICAL)
  DIAMETER=     4.267 M
  LENGTH  =     4.137 M
  VOLUME  =    44.785 M3
  DOME THK=    .00514 M
  CYL THK =    .00852 M
  FS = 1.50,   FNOP= 1.30

PRESSURANT                                        139.534

PRESSURANT TANKS (NO.= 1)                         749.22
  DIA=    1.8549 M
  VOL=     3.342 M3
  THK=    .01565 M
  FS = 1.50,   FNOP= 1.10

FUEL TANK INSULATION                              107.99
OXIDIZER TANK INSULATION                           45.36

ENGINES (NO.= 1)                                   15.88

COMPONENTS AND LINES                              554.74
ENG. MOUNTS,SUPPORTS                             1322.22

TOTAL WET SYSTEM MASS                            25096.7
TOTAL BURNOUT MASS                                5392.7
   (INCL.NON-USABLE PROP. AND GAS)

MASS FRACTION                                       .767
TOTAL IMPULSE                                82182199.9 N-S

             PRESSURE SCHEDULE(N/M2  )    AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =    .2482E+08    INITIAL CHAMBER PRESSURE =0.
INITIAL OX SYS PRESSURE   =    .1069E+07    FINAL OX SYS PRESSURE    =  .1069E+07
INITIAL FU SYS PRESSURE   =    .1138E+07    FINAL FU SYS PRESSURE    =  .1138E+07
```

9 BURNS, CONSTANT THRUST, T/M=0.05

```
    LH2/LO2  MAX PERF  PRESS FED

 VEHICLE MASS  =27215.5 KG    DELTA V=  4511.0 M/S   AVE. ISP=4334.3 N-S/KG

 TOTAL PROPELLANT                             18465.23 KG
   USABLE FUEL                    2493.63
   USABLE OXIDIZER               14961.78
   FUEL TRAPPED                     93.77
   OXID TRAPPED                    548.45
   FUEL START-S/D LOSSES             8.16
   OXID START-S/D LOSSES             8.16
   FUEL BOILOFF                    150.02
   OXIDIZER BOILOFF                201.26

 OXIDIZER TANKS (NO.= 1)                        398.01
  (ELLIPSOIDAL)
   DIAMETER=     3.372 M
   LENGTH  =     2.384 M
   VOLUME  =    14.194 M3
   AVG THK =    .00382 M
   FS = 1.50,  FNOP= 1.30

 FUEL TANKS (NO.= 1)                           1191.09
  (CYLINDRICAL/SQRT(2) ELLIPTICAL)
   DIAMETER=     4.267 M
   LENGTH  =     3.826 M
   VOLUME  =    40.339 M3
   DOME THK=    .00514 M
   CYL THK =    .00852 M
   FS = 1.50,  FNOP= 1.30

 PRESSURANT                                     125.772

 PRESSURANT TANKS (NO.= 1)                      675.32
   DIA=    1.7918 M
   VOL=     3.012 M3
   THK=    .01512 M
   FS = 1.50,  FNOP= 1.10

 FUEL TANK INSULATION                           100.67
 OXIDIZER TANK INSULATION                        42.46

 ENGINES (NO.= 1)                                52.16

 COMPONENTS AND LINES                           554.74
 ENG. MOUNTS,SUPPORTS                          1352.61

 TOTAL WET SYSTEM MASS                        22958.1
 TOTAL BURNOUT MASS                            5135.1
    (INCL.NON-USABLE PROP. AND GAS)

 MASS FRACTION                                   .760
 TOTAL IMPULSE                             75661123.6 N-S

              PRESSURE SCHEDULE(N/M2  )   AT T=294.4 K

 GAS TANK LOCK-UP PRESSURE =   .2482E+08    INITIAL CHAMBER PRESSURE =0.
 INITIAL OX SYS PRESSURE   =   .1069E+07    FINAL OX SYS PRESSURE    =  .1069E+07
 INITIAL FU SYS PRESSURE   =   .1138E+07    FINAL FU SYS PRESSURE    =  .1138E+07
```

9 BURNS, CONSTANT THRUST, T/M=0.01

```
   LH2/LO2  MAX PEF.  PUMP FED

VEHICLE MASS  =27215.5 KG    DELTA V=  5334.0 M/S   AVE. ISP=4314.7 N-S/KG

TOTAL PROPELLANT                          20310.04 KG
  USABLE FUEL                    2734.79
  USABLE OXIDIZER               16408.75
  FUEL TRAPPED                    102.36
  OXID TRAPPED                    598.27
  FUEL START-S/D LOSSES             9.80
  OXID START-S/D LOSSES             9.80
  FUEL BOILOFF                    190.01
  OXIDIZER BOILOFF                256.27

OXIDIZER TANKS (NO.= 1)                      81.38
 (ELLIPSOIDAL)
  DIAMETER=    3.480 M
  LENGTH  =    2.460 M
  VOLUME  =   15.597 M3
  AVG THK =   .00064 M
  FS = 1.50,  FNOP= 1.50

FUEL TANKS (NO.= 1)                         202.17
 (CYLINDRICAL/SQRT(2) ELLIPTICAL)
  DIAMETER=    4.267 M
  LENGTH  =    4.126 M
  VOLUME  =   44.620 M3
  DOME THK=   .00069 M
  CYL THK =   .00114 M
  FS = 1.50,  FNOP= 1.50

PRESSURANT                                  17.865

PRESSURANT TANKS (NO.= 1)                    95.78
  DIA=     .9344 M
  VOL=      .427 M3
  THK=    .00788 M
  FS = 1.50,  FNOP= 1.10

FUEL TANK INSULATION                        107.72
OXIDIZER TANK INSULATION                     45.21

ENGINES (NO.= 1)                             35.38

COMPONENTS AND LINES                        554.29
ENG. MOUNTS,SUPPORTS                       1323.58

TOTAL WET SYSTEM MASS                     22773.4
TOTAL BURNOUT MASS                         3164.0
   (INCL.NON-USABLE PROP. AND GAS)

MASS FRACTION                                .841
TOTAL IMPULSE                          82602947.6 N-S

             PRESSURE SCHEDULE(N/M2  )   AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =   .2482E+08    INITIAL CHAMBER PRESSURE =0.
INITIAL OX SYS PRESSURE   =   .1517E+06    FINAL OX SYS PRESSURE    =  .1517E+06
INITIAL FU SYS PRESSURE   =   .1517E+06    FINAL FU SYS PRESSURE    =  .1517E+06
```

9 BURNS, CONSTANT THRUST, T/M=0.015

LH2/LO2 MAX PEF. PUMP FED

VEHICLE MASS =27215.5 KG DELTA V= 4968.2 M/S AVE. ISP=4363.8 N-S/KG

```
TOTAL PROPELLANT                                    19419.85 KG
  USABLE FUEL                          2620.15
  USABLE OXIDIZER                     15720.88
  FUEL TRAPPED                           97.54
  OXID TRAPPED                          572.18
  FUEL START-S/D LOSSES                   9.80
  OXID START-S/D LOSSES                   9.80
  FUEL BOILOFF                          166.16
  OXIDIZER BOILOFF                      223.36

OXIDIZER TANKS (NO.= 1)                                 79.02
 (ELLIPSOIDAL)
  DIAMETER=     3.429 M
  LENGTH   =    2.424 M
  VOLUME   =   14.923 M3
  AVG THK  =   .00064 M
  FS = 1.50,  FNOP= 1.50

FUEL TANKS (NO.= 1)                                    192.86
 (CYLINDRICAL/SQRT(2) ELLIPTICAL)
  DIAMETER=     4.267 M
  LENGTH   =    3.978 M
  VOLUME   =   42.514 M3
  DOME THK=    .00069 M
  CYL THK  =   .00114 M
  FS = 1.50,  FNOP= 1.50

PRESSURANT                                              17.031

PRESSURANT TANKS (NO.= 1)                               91.31
  DIA=     .9196 M
  VOL=      .407 M3
  THK=    .00776 M
  FS = 1.50,  FNOP= 1.10

FUEL TANK INSULATION                                   104.25
OXIDIZER TANK INSULATION                                43.90

ENGINES (NO.= 1)                                        39.92

COMPONENTS AND LINES                                   554.29
ENG. MOUNTS,SUPPORTS                                  1313.60

TOTAL WET SYSTEM MASS                                21856.0
TOTAL BURNOUT MASS                                    3105.9
   (INCL.NON-USABLE PROP. AND GAS)

MASS FRACTION                                            .839
TOTAL IMPULSE                                     80039443.0 N-S

              PRESSURE SCHEDULE(N/M2  )    AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =   .2482E+08   INITIAL CHAMBER PRESSURE =0.
INITIAL OX SYS PRESSURE   =   .1517E+06   FINAL OX SYS PRESSURE    =  .1517E+06
INITIAL FU SYS PRESSURE   =   .1517E+06   FINAL FU SYS PRESSURE    =  .1517E+06
```

9 BURNS, CONSTANT THRUST, T/M=0.1

LH2/LO2 MAX PEF. PUMP FED

VEHICLE MASS =27215.5 KG DELTA V= 4419.6 M/S AVE. ISP=4530.5 N-S/KG

TOTAL PROPELLANT		17795.61 KG
USABLE FUEL	2402.02	
USABLE OXIDIZER	14412.13	
FUEL TRAPPED	90.47	
OXID TRAPPED	528.71	
FUEL START-S/D LOSSES	9.80	
OXID START-S/D LOSSES	9.80	
FUEL BOILOFF	146.27	
OXIDIZER BOILOFF	196.42	

OXIDIZER TANKS (NO.= 1) 74.56
(ELLIPSOIDAL)
DIAMETER= 3.330 M
LENGTH = 2.355 M
VOLUME = 13.677 M3
AVG THK = .00064 M
FS = 1.50, FNOP= 1.50

FUEL TANKS (NO.= 1) 176.94
(CYLINDRICAL/SQRT(2) ELLIPTICAL)
DIAMETER= 4.267 M
LENGTH = 3.727 M
VOLUME = 38.913 M3
DOME THK= .00069 M
CYL THK = .00114 M
FS = 1.50, FNOP= 1.50

PRESSURANT 15.584

PRESSURANT TANKS (NO.= 1) 83.55
DIA= .8928 M
VOL= .373 M3
THK= .00753 M
FS = 1.50, FNOP= 1.10

FUEL TANK INSULATION	98.32
OXIDIZER TANK INSULATION	41.42
ENGINES (NO.= 1)	96.16
COMPONENTS AND LINES	554.29
ENG. MOUNTS, SUPPORTS	1303.62
TOTAL WET SYSTEM MASS	20240.1
TOTAL BURNOUT MASS (INCL.NON-USABLE PROP. AND GAS)	3063.6
MASS FRACTION	.831
TOTAL IMPULSE	76179378.5 N-S

PRESSURE SCHEDULE(N/M2) AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =	.2482E+08	INITIAL CHAMBER PRESSURE =	0.
INITIAL OX SYS PRESSURE =	.1517E+06	FINAL OX SYS PRESSURE =	.1517E+06
INITIAL FU SYS PRESSURE =	.1517E+06	FINAL FU SYS PRESSURE =	.1517E+06

9 PERIGEE BURNS, CONSTANT THRUST, T/M=0.05

LH2/LO2 MIN LENGTH PUMP FED MR=6

VEHICLE MASS =27215.5 KG DELTA V= 4526.3 M/S AVE. ISP=4481.4 N-S/KG

TOTAL PROPELLANT		18159.37 KG
USABLE FUEL	2449.71	
USABLE OXIDIZER	14698.25	
FUEL TRAPPED	89.48	
OXID TRAPPED	524.64	
FUEL START-S/D LOSSES	10.43	
OXID START-S/D LOSSES	10.43	
FUEL BOILOFF	151.92	
OXIDIZER BOILOFF	224.51	

OXIDIZER TANKS (NO.= 1)	436.68
(TOROIDAL)	
INNER DIA= 1.455 M	
OUTER DIA= 4.267 M	
HEIGHT = 1.406 M	
VOLUME = 13.958 M3	
AVG THK = .00306 M	
FS = 1.50, FNOP= 1.30	
FUEL TANKS (NO.= 1)	156.33
(CYLINDRICAL/SQRT(2) ELLIPTICAL)	
DIAMETER= 4.267 M	
LENGTH = 3.781 M	
VOLUME = 39.692 M3	
DOME THK= .00069 M	
CYL THK = .00114 M	
FS = 1.50, FNOP= 1.30	
PRESSURANT	15.912
PRESSURANT TANKS (NO.= 1)	85.31
DIA= .8991 M	
VOL= .381 M3	
THK= .00759 M	
FS = 1.50, FNOP= 1.10	
FUEL TANK INSULATION	99.60
OXIDIZER TANK INSULATION	58.16
ENGINES (NO.= 1)	64.41
COMPONENTS AND LINES	584.23
ENG. MOUNTS,SUPPORTS	1131.26
TOTAL WET SYSTEM MASS	20791.3
TOTAL BURNOUT MASS	3246.0
(INCL.NON-USABLE PROP. AND GAS)	
MASS FRACTION	.825
TOTAL IMPULSE	76850900.7 N-S

PRESSURE SCHEDULE(N/M2) AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =	.2482E+08	INITIAL CHAMBER PRESSURE =0.	
INITIAL OX SYS PRESSURE =	.1517E+06	FINAL OX SYS PRESSURE =	.1517E+06
INITIAL FU SYS PRESSURE =	.1517E+06	FINAL FU SYS PRESSURE =	.1517E+06

9 PERIGEE BURNS, CONSTANT THRUST, T/M=0.1

LH2/LO2 MIN LENGTH PUMP FED MR=6

VEHICLE MASS =27215.5 KG DELTA V= 4446.4 M/S AVE. ISP=4530.5 N-S/KG

TOTAL PROPELLANT		17868.84 KG
USABLE FUEL	2409.12	
USABLE OXIDIZER	14454.72	
FUEL TRAPPED	88.44	
OXID TRAPPED	518.52	
FUEL START-S/D LOSSES	15.42	
OXID START-S/D LOSSES	15.42	
FUEL BOILOFF	148.08	
OXIDIZER BOILOFF	219.11	

OXIDIZER TANKS (NO.= 1) 427.19
(TOROIDAL)
INNER DIA= 1.485 M
OUTER DIA= 4.267 M
HEIGHT = 1.391 M
VOLUME = 13.732 M3
AVG THK = .00301 M
FS = 1.50, FNOP= 1.30

FUEL TANKS (NO.= 1) 154.06
(CYLINDRICAL/SQRT(2) ELLIPTICAL)
DIAMETER= 4.267 M
LENGTH = 3.740 M
VOLUME = 39.097 M3
DOME THK= .00069 M
CYL THK = .00114 M
FS = 1.50, FNOP= 1.30

PRESSURANT 15.670

PRESSURANT TANKS (NO.= 1) 84.01
DIA= .8945 M
VOL= .375 M3
THK= .00755 M
FS = 1.50, FNOP= 1.10

FUEL TANK INSULATION	98.62
OXIDIZER TANK INSULATION	57.84
ENGINES (NO.= 1)	96.16
COMPONENTS AND LINES	584.23
ENG. MOUNTS,SUPPORTS	1131.26
TOTAL WET SYSTEM MASS	20517.9
TOTAL BURNOUT MASS	3256.0
(INCL.NON-USABLE PROP. AND GAS)	
MASS FRACTION	.822
TOTAL IMPULSE	76404490.8 N-S

PRESSURE SCHEDULE(N/M2) AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =	.2482E+08	INITIAL CHAMBER PRESSURE =	0.
INITIAL OX SYS PRESSURE =	.1517E+06	FINAL OX SYS PRESSURE =	.1517E+06
INITIAL FU SYS PRESSURE =	.1517E+06	FINAL FU SYS PRESSURE =	.1517E+06

APPENDIX C

SYMBOLS

A	Area
ACS	Altitude Control System
ASE.	Airborne Support Equipment
b	Wrap Radial Rib Minor Axis Diameter
BT	Box Truss
cm	Centimeter
d	Wrap Radial Rib Major Axis Diameter
E	Modulus of Elasticity
f	Frequency
FPA	Flight Path Angle
g	Acceleration
GEO	Geosynchronous Earth Orbit
HC	Hoop and Column
hr	Hour
HZ	Hertz
I	Moment of Inertia
I/F	Interface
Kg	Kilogram
km	Kilometer
kN	Kilonewton
kW	Kilowatt
LCH_4	Liquid Methane
LEO	Low Earch Orbit
LH_2	Liquid Hydrogen
LO_2	Liquid Oxygen
LSS	Large Space Systems
LTPS	Low Thrust Propulsion System
m	Meters
MLI	Multilayer Insulation
mm	Millimeter
MMH	Monomethylhydrazine
mps	Meters Per Second
MR	Mixture Ratio
N	Newtons
N_2O_4	Nitrogen Tetroxide
ODSRS	Orbiting Deep Space Relay Station
OTV	Orbit Transfer Vehicle
P	Load
PSCS	Personal Communication Spacecraft
r	Radius
RA	Radio Astronomy
RF	Radio Frequency
rms	Root Mean Square
RP-1	Kerosene
SBR	Space Based Radar
sec	Seconds
SETI	Search for Extraterrestrial Intelligence
SOFI	Spray on Foam Insulation
SPS	Space Power Satellite

SYMBOLS (Continued)

STS	Space Transportation System
t	Wrap Radial Rib Thickness
T	Temperature
ΔT	Change in Temperature
T_R	Ramp Time
T/M	Thrust-to-Mass
v	Volts
ΔV	Change in velocity
VLBI	Very Long Based Interferometer
WRR	Wrap Radial Rib
α	Coefficient of Thermal Expansion
δ	Deflection
ϵ	Ratio of Engine Exit Diameter to Throat Diameter
γ	Knock Down Factor
λ	Mass Fraction
ρ	Density
σ	Stress

APPENDIX D

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